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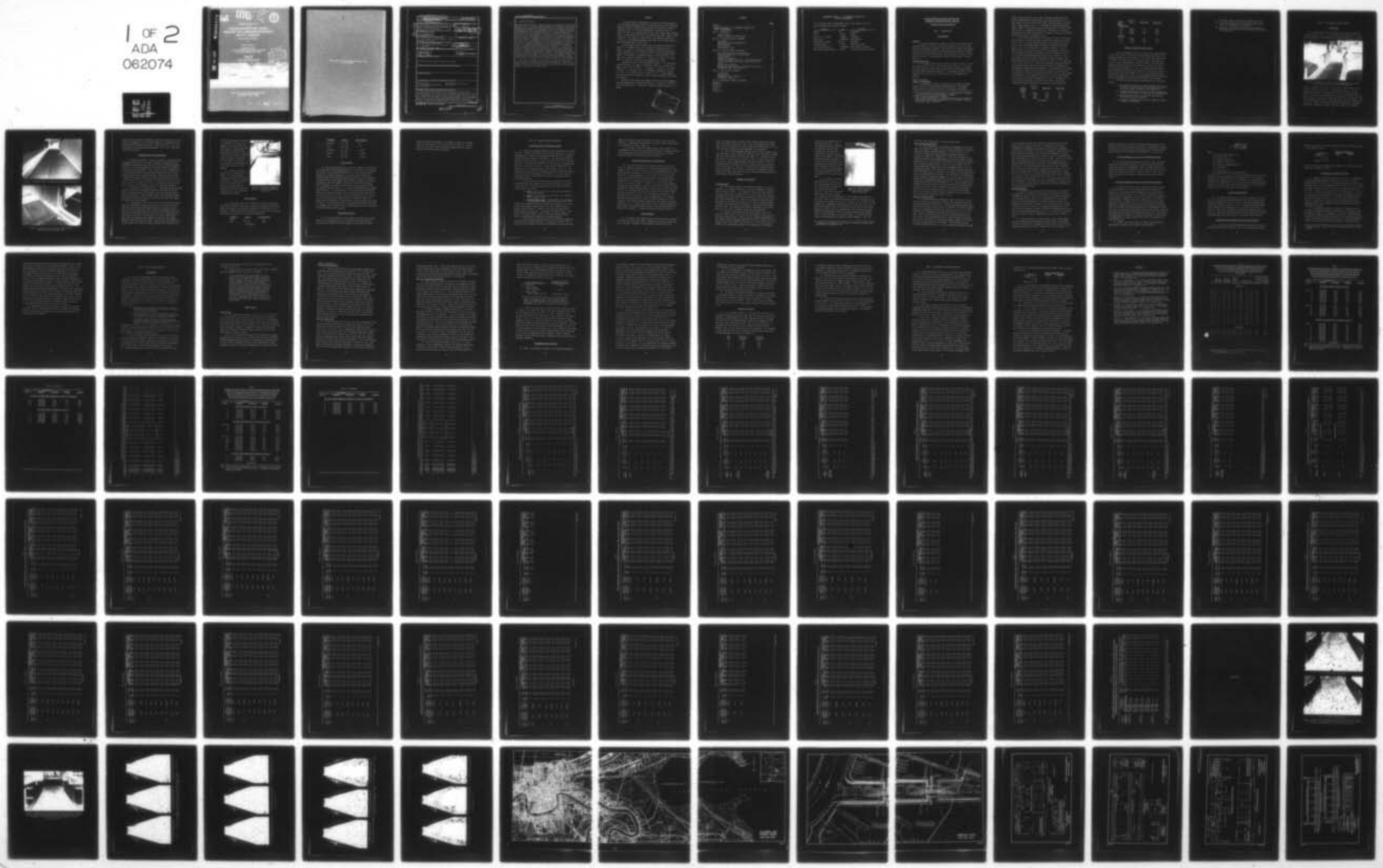

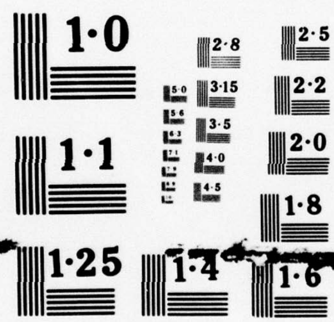
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TECHNICAL REPORT H-78-16

FILLING AND EMPTYING SYSTEM NEW SHIP LOCK, MISSISSIPPI RIVER-GULF OUTLET, LOUISIANA

Hydraulic Model Investigation

by

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Final Report

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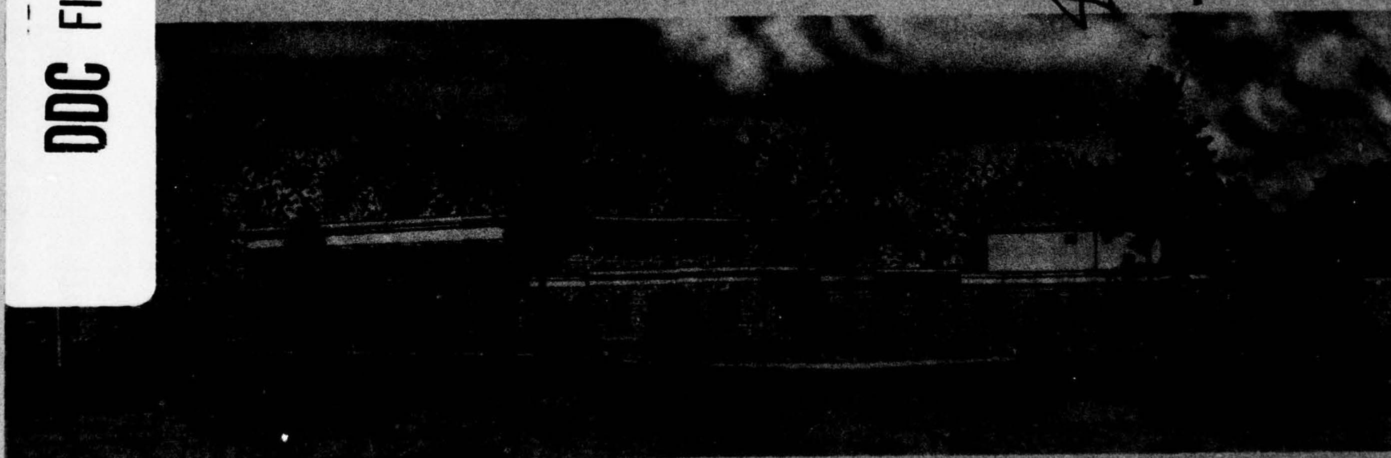

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The proposed New Ship Lock for the Mississippi River-Gulf Outlet, Louisiana, will be 150 ft wide by 1290 ft long (pintle to pintle) and will have lifts varying from 1.0 to 18.4 ft as well as reverse heads up to 3.0 ft. Two sets of miter gates are planned to care for reverse heads. Since the proposed lock is some 40 ft wider than any locks previously designed in the United States and will be used by both ship and barge traffic and will be subjected to reverse head conditions, a hydraulic model investigation of the filling and — CONT'
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emptying system was required. Results of tests of the hydraulic system for the proposed lock in a 1:25-scale model are presented in this report. The original intake and outlet designs which must perform as both intakes and outlets were investigated and found to be satisfactory. Tests of 20 sidewall port manifold arrangements resulted in the recommendation of the type 15 sidewall port manifold arrangement. This arrangement consisted of 20 original design ports (throats 5 by 3.25 ft), spaced 38 ft on centers in each 18.5 by 18.5-ft wall culvert with the ports staggered in opposite walls. There was 22.79 percent of chamber upstream of the manifold, 57.44 percent of the chamber with manifold, and 19.77 percent of the chamber downstream of the manifold. Port-to-culvert area ratio was 0.95. Triangular floor recesses 15 by 15 by 3 ft deep were installed at the 7 upstream ports in each wall and rectangular floor recesses 15 by 15 by 3 ft deep were installed in the 13 downstream ports. The floor of the culvert, sidewall port manifold, and floor recesses were at a common invert elevation with the lock chamber floor 3 ft higher. In order for the lock to perform satisfactorily for deep-draft ships, it will be necessary to construct the chamber floor at a lower invert elevation than for barge tows. Sufficient ship model input data were presented to permit necessary economic analysis to determine the feasibility of the type 15 (recommended) design manifold port system as developed with some lowering of the chamber floor and manifolds between the miter gates. This input together with projected traffic requirements, head and stage duration studies, and other pertinent considerations will be used in the economic analysis and sidewall port system evaluation.

The type 15 (recommended) design sidewall port system as developed is considered optimum for barge tows and will be satisfactory for ships with the proper clearance provided between the bottom of the ships and floor of the lock chamber. For the culvert size and sidewall port system selected, the optimum elements were developed from model tests.

PREFACE

A hydraulic model investigation to verify the proposed design of the filling and emptying system for the New Ship Lock at the Mississippi River-Gulf Outlet, Louisiana, was authorized by the Office, Chief of Engineers (OCE), in the second endorsement, dated 18 May 1971, to a letter from the U. S. Army Engineer District, New Orleans (LMN), through the U. S. Army Engineer Division, Lower Mississippi Valley (LMVD), dated 6 May 1971. The study was accomplished in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) during the period September 1972 to March 1975.

The investigation was conducted under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and J. L. Grace, Jr., Chief of the Hydraulic Structures Division, and under the direct supervision of G. A. Pickering, Chief of the Locks and Conduits Branch. The engineer in immediate charge of the model was Mr. J. H. Ables, Jr., assisted by Messrs. H. O. Turner, C. L. Dent, H. H. Allen, and J. A. McLaurin. This report was prepared by Mr. Ables.

During the course of the investigation, Messrs. J. P. Davis, Consultant for OCE; T. E. Murphy, Consultant for WES; R. E. Louque, H. E. Walker, and M. Dove of LMVD; L. J. Rousseau, E. B. Barton, I. G. Moss, M. Facio, J. G. Williams, and G. E. Breerwood of LMN; and R. Lucius, T. C. Cox, T. D. Wardlaw, and R. O. Smith of the U. S. Army Engineer District, Vicksburg, visited WES to observe model operations and discuss test results.

Directors of WES during the conduct of the tests and the preparation and publication of this report were BG E. D. Peixotto, CE, COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
tons (2000 lb, mass)	907.185	kilograms
feet per second	0.3048	metres per second
cubic feet per second	0.02831685	cubic metres per second
feet per second per second	0.3048	metres per second per second

FILLING AND EMPTYING SYSTEM, NEW SHIP LOCK

MISSISSIPPI RIVER-GULF OUTLET, LOUISIANA

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

Location

1. New Ship Lock will be located in a canal in St. Bernard Parish, Louisiana (Plate 1), about 12 miles* downstream from the foot of Canal Street in New Orleans, Louisiana. The lock site is located 1 mile northeast of the canal entrance into the Mississippi River (mile 83.0 AHP**). The canal will be 500 ft wide, with a bottom elevation of -50.0 ft mlg,† and will connect to the Mississippi River-Gulf Outlet (MR-GO) Canal at mile 53.7.

Description of lock

2. The 150-ft-wide by 1200-ft-long lock (1290 ft pintle to pintle) will have a top wall el 22.0 and a sill el -50.0 (Plate 2). The lock will have sidewall culverts and intake manifolds, and sidewall chamber ports and outlet manifolds (Plates 3-5). The sidewall culverts in each wall will be 18.5 by 18.5 ft, with invert el -50.0 throughout the system.

Basis of hydraulic design of lock system

3. The hydraulic design of New Ship Lock was based on a mathematical analysis of the filling and emptying system. The methods, design criteria, and factors used are in accordance with Engineer

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

** AHP, river miles Above Head of Passes.

† All structure elevations (el, cited herein) are in feet referred to mean low gulf (mlg) and all stages are in feet referred to mean sea level (msl); (mlg = -0.78 msl).

Manual 1110-2-1604 (draft, April 1963), "Hydraulic Design-Navigation Locks," supplemented by recent model studies and practices in the U. S. Army Engineer Districts, New Orleans (LMN), Vicksburg (LMK), and Mobile (SAM). Model studies by the U. S. Army Engineer Waterways Experiment Station (WES)[1-4] were used as a guide where applicable. The four referenced reports are summarized in Reference 5 together with information developed in this report as guidance for design of sidewall port filling and emptying systems for navigation locks.

4. Two sets of miter gates were provided to care for normal and reverse heads. The lock and culvert system were designed for a normal lift of 18.4 ft, selected from Mississippi River project design flow line el 15.9, with minimum stage of record on the Paris Road Bridge gage of el -2.5 being selected for computation purposes. For the reverse head, 14.6 ft was selected for structural design of the lock and is based on the land-side Standard Project Hurricane flow line of el 13.0, and the minimum Mississippi River stage of record el -1.6, taken from the stage frequency hydrographs at Carrollton gage. The maximum observed reverse head for period of record is 2.1 ft (land side el 7.6; river side el 5.5). Since the operating reverse heads would be rather small and infrequent, this would not justify a compromise in the hydraulic system and reverse heads were not considered in the design of the system. Other criteria and factors selected or assumed were a filling time of 7.5 min, a valve-operation time of 2 min, a lock filling coefficient of 0.75, an emptying coefficient of 0.63, a valve factor of 0.5, and an overtravel from momentum of 0.8 ft. The duration of a 3-ft lift at the lock has a 48 percent time period. Normal and reverse head stages investigated in the model are tabulated below:

Heads	Duration %	Upper Pool	Lower Pool
Normal			
18.4	Design	15.9	-2.5
14.0	1.20	12.7	-1.3
11.0	8.94	10.9	-0.1
7.0	28.09	6.6	-0.4

(Continued)

Heads	Duration %	Upper Pool	Lower Pool
Normal (Continued)			
5.0	37.17	4.8	-0.2
3.0	48.26	2.0	-1.0
2.0	59.66	1.2	-0.8
1.0	80.70	0.4	-1.6
Reverse			
14.6	Design	13.0	-1.6
2.1	0.01	5.1	3.0
1.0	0.05	0.5	-0.5

Purpose of Hydraulic Model Studies

5. Since the proposed lock will be used by both ship and barge traffic, the criteria for design and operation may differ from locks designed primarily for barge traffic or for locks built specifically for ships. The lock size of 150 ft wide by 1200 ft long with sill el -50 ft mlg is unprecedented in width and depth. The filling and emptying system must perform satisfactorily for lifts up to 18.4 ft as well as reverse heads up to 3 ft. The original design sidewall port manifold was developed by extrapolation of recent test results of 84- and 110-ft-wide lock chambers. The 1:25-scale hydraulic model permitted investigation of the filling and emptying system and development of refinements that could be incorporated in the prototype.

6. The model testing program was undertaken for the following reasons:

- a. To evaluate the intake and outlet manifolds that will be required to operate as intake and discharge ports due to the reverse heads indigenous to the proposed site.
- b. To make observations of conditions in the upstream canal approach and performance of the guide wall configurations.
- c. To measure hawser forces on barge tows and ships and reduce them to criteria limits.
- d. To observe turbulence inside the lock chamber and reduce turbulence if necessary.

e. To measure pressure conditions throughout the system.

f. To provide an opportunity to develop refinements which could be incorporated in the prototype.

g. To provide a satisfactory design filling and emptying system that can be expected to perform efficiently during its expected life.

PART II: THE MODEL AND TEST PROCEDURE

Description

7. A model (Plate 2) of the sidewall port filling and emptying system was constructed to a scale of 1:25, and reproduced 400 ft of the upstream approach, twin sidewall intake manifolds (Figure 1), the lock

Figure 1. General view of model looking downstream with original design floating guide walls and intake manifolds

chamber, sidewall ports (Figure 2) and culverts, twin sidewall outlet manifolds (Figure 3), and 100 ft of downstream approach. The lock chamber was constructed of plywood and wood. The intake manifolds, culverts, valve wells, and outlets were constructed of plastic and sheet metal, and the port blocks were molded of a resin and sand mixture. The culvert valves, constructed of sheet metal and fitted with rubber seals to prevent leakage, were raised and lowered automatically at predetermined rates. Twenty-four barges, each 195 ft long by 35 ft wide by

Figure 2. Downstream view of original design sidewall port manifold

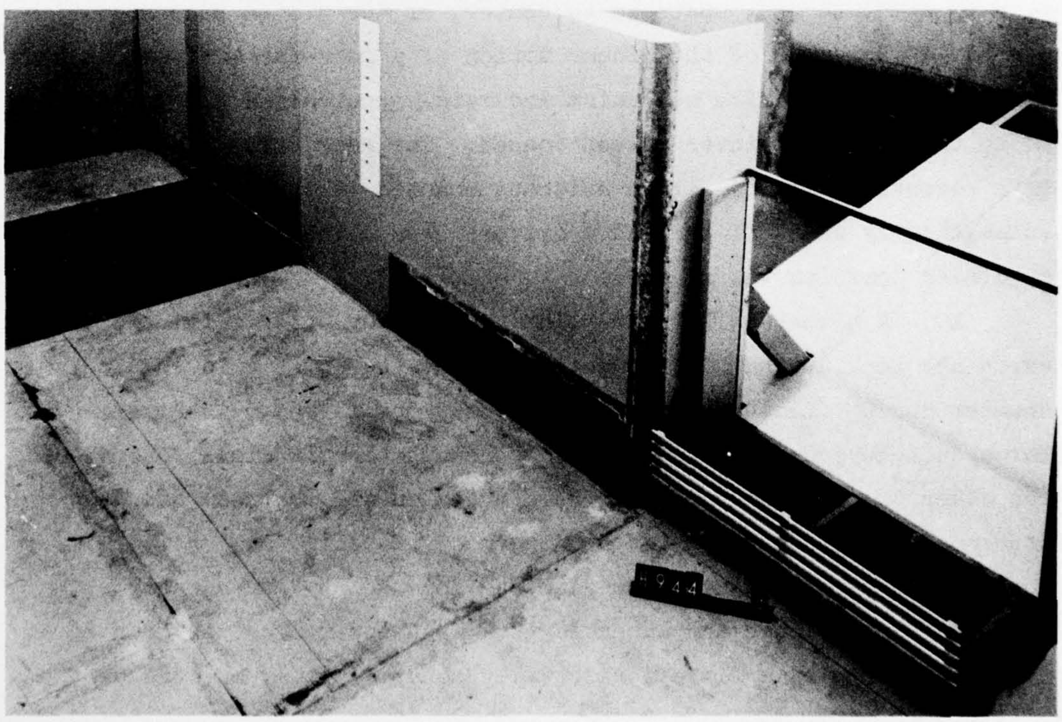

Figure 3. Upstream view of original design outlet manifold and floating guide wall

16 ft deep, were loaded with weights to produce the desired 9- and 12-ft drafts. The makeup of 12-, 18-, and 24-barge tows together with displacements are tabulated in Plate 6. A model ship 900 ft long, 140 ft wide, and 55 ft deep permitted investigation of 30-, 37.5-, and 45-ft ship drafts (Plate 7).

Appurtenances and Instrumentation

8. Water was supplied to the model through a circulating system. The headbay and tailbay of the model contained a skimming weir that maintained constant upper and lower pools during filling and emptying operations. A vertical adjustment of the weirs permitted simulation of any desired pool elevation. Pitot tubes were used to determine the velocity and direction of flow; dye and confetti were used to study subsurface and surface current directions. Pressure cells were used to measure the pressure below the filling valve and record the level of water surface in the lock chamber. Differential pressure cells were used to record the difference in the lock chamber water-surface elevation from end to end, upstream to center, or downstream to center.

9. By means of the linear motion of a gear-rack-driven cam plate, the culvert-valve drive mechanism accurately controlled the rate at which the culvert tainter valves opened. The gear drive was powered by a reversible motor. Limit switches mounted on the gear-rack guide automatically shut off the valve drivers when either the fully opened or closed position was reached.

10. A hawser-pull (force link) device for determining the transverse and longitudinal forces acting on the tow or ship in the lock chamber during filling and emptying operations is shown in Figure 4. Three such devices were used: one to measure longitudinal forces, and the other two to measure transverse forces on the upstream and downstream end of the tow, or bow and stern of the ship, respectively. These links were machined from aluminum and had SR-4 strain gages cemented to the inner and outer edges. When the device was mounted on the tow or ship by a fixed horizontally mounted plate, one end of the

link was pin-connected to the tow or ship while the other end was engaged to a fixed vertical rod that was free to move up and down with changes in water-surface elevation in the lock. Any horizontal motion of the tow or ship caused the links to deform and vary the signal to a recorder. The links were calibrated by inducing deflections with known weights.

11. Data were recorded graphically on a commercial recorder. The sensing elements (mechanical-to-electrical conversion devices) located at various points on the model were connected by shielded cables to amplifiers where the outputs were stepped up to the level required for graphical recording.

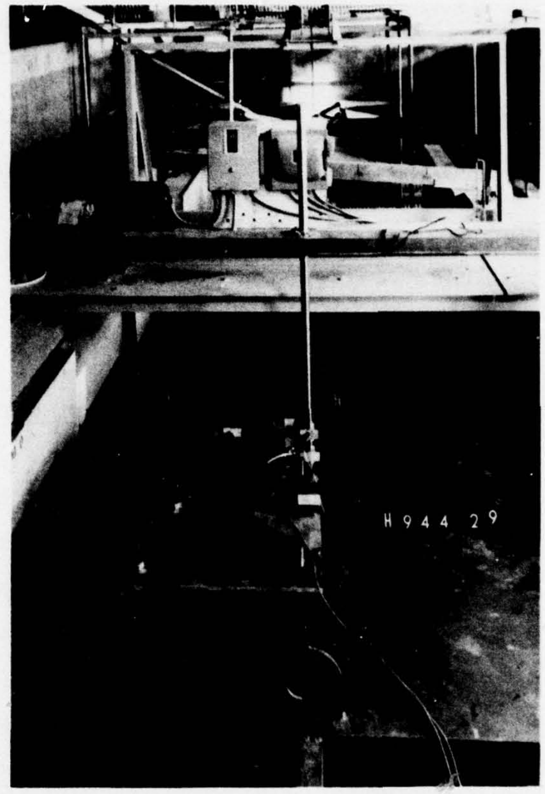

Figure 4. Hawser-pull measuring device (force links) mounted on bow of ship

Scale Relations

12. The accepted equations of hydraulic similitude, based upon the Froudian relations, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and the prototype. General relations for transference of model data to prototype equivalents are presented in the following tabulation:

Dimension	Ratio	Scale Relation
Length	$L_r = L$	1:25
Area	$A_r = L_r^2$	1:625

(Continued)

Dimension	Ratio	Scale Relation
Velocity	$V_r = L_r^{1/2}$	1:5
Time	$T_r = L_r^{1/2}$	1:5
Discharge	$Q_r = L_r^{5/2}$	1:3,125
Weight	$W_r = L_r^3$	1:15,625
Force	$F_r = L_r^3$	1:15,625

Test Procedure

13. Tests were conducted in the model to observe flow conditions in the upstream and downstream approaches in the vicinity of the intakes and outlets, to investigate the suitability of the intake and outlet manifolds, to measure pressures at the valves, and to develop the optimum sidewall port filling and emptying system from the standpoint of hawser forces on both barge tows and ships in lockage and turbulence conditions in the lock chamber. Evaluation of the various sidewall port arrangements was based on data obtained during typical filling and emptying operations with 1- to 18.4-ft lifts and appropriate submergences (Table 1). In determination of flow distribution and pressure conditions, fixed-head (steady flow) conditions were used with the culvert valves either fully open or closed and miter gates open or closed. In tests during which the lock was filled or emptied, single valve speeds were investigated in accordance with the valve opening rate shown in Plate 8. For steady-flow tests, water-surface elevations within the lock chamber were set from filling or emptying curves for the corresponding initial lift and valve opening.

Presentation of Data

14. In the presentation of test results, the data are not introduced in the chronological order in which the tests were conducted. Instead as each element of the lock system is considered, all tests

conducted thereon are discussed. All barge tow tests are discussed, along with development of the lock structure in PART III. All ship tests are discussed in PART IV and were conducted with the system developed during the barge test program.

PART III: BARGE TOW TESTS AND RESULTS

Upstream Approach and Intake Manifolds

15. Sufficient upstream approach area was reproduced in the model (Plate 2) to ensure that natural flow conditions would exist at the intake manifolds. Details of the approach channel and type 1 (original) intakes are shown in Figure 1 and Plate 3. The intake manifolds have eight ports, 8 ft wide by 14 ft high, with invert el -45.5 in each lock wall face. The top of the intakes at el -31.5 provides a minimum water cushion of 32.3 ft at el 0.0 msl. For the 18.4-ft design lift, the upper pool is el 15.9 and provides a water cushion of 48.2 ft. The transitions in the intake are designed to provide a relatively uniform increase in velocities upstream and downstream of the ports and into the culvert valves. The intakes will be used as discharge outlets during reverse heads.

16. Flow conditions in the upstream lock approach and at the intake manifolds were observed during filling operations to evaluate vortex tendencies. The following terminology is used in describing vortex action in the model.

- a. Swirl - a vortex with only a slight concave depression in the water surface.
- b. Vortex - a vortex with an air cavity or tail extending below the water surface.
- c. Air-entraining vortex - a vortex with a tail extending into the culvert intake (none observed in model test).

During filling operations with the culvert valve opened in 2 or 4 min, a vortex occasionally formed over the left wall intake manifold as shown in Photos 1a and 1b. However, this vortex was weak and not strong enough to entrain air. A rounding of the sharp corner of the wall at sta 2+50.8U (Plate 3) with a 10-ft radius would probably reduce or eliminate this tendency if considered necessary.

17. Under steady-flow conditions, flow distribution through the intake manifold ports was excellent. Velocities at the wall face of the ports did not exceed 6 fps and flow distribution did not vary more

than 1/2 percent from equal distribution for each of the eight ports (Plate 9). Steady-flow pressure data are listed in Table 2 and piezometer locations are shown in Plate 10.

18. The type 1 (original) intake manifold design (Plate 3) is recommended for inclusion in the prototype structure. Average pressures in the intake manifold recorded during a 4-min valve time filling operation with an 18.4-ft lift are listed in Table 3.

Pressures Downstream of Filling Valves

19. The culvert valves will be patterned after the Holt Lock valves.[6] Pressures representative of those expected immediately downstream of the filling valves were recorded with piezometers and a flush-mounted pressure transducer in the roof of the culvert at sta 1+69.5 (Plate 10). Average pressures in the vicinity of the filling valve during a 4-min valve operation with the type 15 (recommended) design system and 18.4-ft design lift (upper pool el 15.9 and lower pool el -2.5) are listed in Table 3. Plate 11 is a plot of high, observed average, and low pressures recorded with the pressure transducer during the period of minimum pressures that occurred during filling operations with 1-, 2-, and 4-min valve times for design lift conditions. These pressures were never more than 6 ft below lower pool and were 23 ft above the roof of the culvert. With the high water-surface cushion provided over the culverts and valves, minimum pressures will not be a problem. There were no adverse pressures at the filling or emptying valves for 1-, 2-, or 4-min valve times. Table 5 presents pressures in the vicinity of the emptying valve during a 4-min valve operation for design lift conditions. Piezometer locations are shown in Plate 10.

Outlet Manifold

20. A sidewall outlet manifold patterned after the New Poe Lock,[7] St. Mary's River, Sault Ste. Marie, Michigan, was selected for the ship lock. The type 1 (original) outlet manifolds (Plate 5) have five

ports 10 ft wide by 18.5 ft high on 19-ft centers at the face of each wall. The invert elevation is -50.0. This is a minimum water cushion depth of 48.3 ft based on the 18.4-ft design lift condition with -2.5 ft, msl, lower pool elevation at the beginning of the operation.

21. Photo 2 shows maximum discharge from the outlet during a 2-min valve operation. Under steady-flow conditions, flow distribution through the outlet manifold ports was very good (Plate 12). Velocities at the wall face of the ports did not exceed 13.5 fps. Steady-flow pressures are listed in Table 4 and piezometer locations are shown in Plate 10. Average pressures throughout the outlet during a 4-min valve operation are listed in Table 5. The type 1 (original) outlet manifold shown in Plate 5 was adopted for inclusion in the type 15 (recommended) system. Under reverse head conditions, the outlet performed satisfactorily as an intake during filling operations.

Sidewall Port Manifold

Original design

22. The original sidewall port manifold consisted of 20 ports, spaced 38 ft on centers in each wall, with ports staggered in opposite walls as shown in Plate 4. As a matter of record, the basic manifold design was developed by extrapolation of recent sidewall port filling and emptying test data collected on an 84-ft-wide lock and three 110-ft-wide locks (References 1-4). Thus the port spacing, number of ports, port geometry, and manifold position for the type 1 (original) design was based on previous model investigations. The port-to-culvert-area ratio was 0.95. All sidewall port manifold arrangements were investigated with the type 1 (original) intake and outlet manifolds.

23. Figure 5 shows dyed flow from three sidewall ports and indicates that the path of the jets into the chamber is normal and the 38-ft-port spacing is good. Photos 3a-3f are sequence photographs of lock chamber surface turbulence observed prior to the start of a filling operation with a 2-min valve time and at 2.0, 3.5, 5.0, 6.25, and 7.5 min after the valve started opening. The distribution of turbulence

across the lock chamber was considered satisfactory. Closer port spacing would have resulted in excessive contact between opposing jets and would have caused severe turbulence in the center of the chamber. Wider port spacing would have resulted in little or no contact between opposing jets and would have caused more turbulence along the lock walls. The 38-ft spacing appears to be most satisfactory for the port manifold of the 150-ft-wide lock.

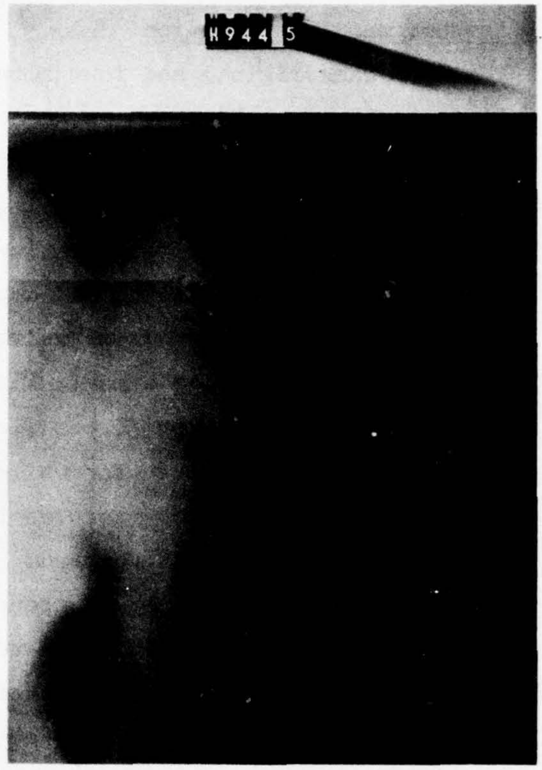

Figure 5. Path of jets from ports after 2-min filling valve is open full

24. The effect of filling and emptying valve times of 1, 2, and 4 min on hawser forces with 24- and 12-barge tows laden to a 12-ft draft are plotted in Plate 13. Since the lock would be used by ships as well as barge tows, barge tows were investigated at a 12-ft draft rather than the usual 9-ft draft on inland waterways simply because the clearance under the barge to the chamber floor was not critical, as is normally the case, and much more submergence* was available due to ship use. Also, due to large lock capacity (150 ft wide by 1200 ft long), the lock can accommodate more barges; and this, combined with the 12-ft draft, provided greater tow displacements (Plate 6) than have previously been experienced on inland waterways in the United States or in model investigations of the navigation lock systems on these waterways. Tests at a

* Submergence is defined as the difference in elevation between lower pool and the lock chamber floor.

9-ft draft would simply result in reduced hawser force.

Effect of manifold position

25. The original and four alternative arrangements of the side-wall ports (types 1-5) shown in Plate 14 were investigated to study the effects of manifold position and port-to-culvert-area (0.95, 1.00, and 1.04) on hawser forces and filling and emptying times with a 24-barge tow (Plate 15). Examination of these data indicated the necessity to modify the filling and emptying system as designed to reduce hawser forces, or to use slower valve times with resulting increases in both filling and emptying times. Plates 13 and 15 indicate that upstream longitudinal hawser forces were the maximum forces in all port arrangements tested. These forces can be reduced by adding deflectors above the chamber floor or recesses in the chamber floor and angling the flow in the upstream ports upstream. Even with properly designed ports there is usually a downstream component to the jets issuing from the upstream ports in the manifold where velocity past the ports is quite high. Rather than deflectors above the chamber floor, it was determined that recesses in the floor (Plate 15) were preferred which would necessitate lowering the culvert and port inverts by the height of the recesses required to better dissipate and direct jet flow from the upstream ports in the chamber manifold toward the upstream end of the chamber and better balance longitudinal hawser forces.

Effect of floor recesses

26. Fourteen alternate arrangements (types 7-20, Plate 14) with floor recesses were investigated to optimize the system and reduce the upstream longitudinal hawser forces. The upstream and downstream hawser forces were also better balanced with the addition of the floor recesses. Types 7-14 arrangements involved floor recesses 15 by 15 by 2 ft deep and types 15-20 arrangements involved floor recesses 15 by 15 by 3 ft deep. Plate 16 presents selected filling and emptying data for each size recess. The original design 20-port manifold location was varied with the 7 upstream port floor recesses triangular-shaped to force some flow into the upstream end of the chamber. Data obtained with the 3-ft-deep recesses and the 6, 7, 8, and 9 upstream ports angled upstream

with the 20-port manifold positioned in the original position in the chamber are also shown in Plate 16. From these data, the type 15 (recommended) arrangement was selected as the best port arrangement tested with floor recesses. The type 15 arrangement consisted of 20 original design ports spaced 38 ft on centers and staggered in opposite walls with the most upstream port on the left wall at sta 2+56 and the most downstream port on the right wall at sta 9+97. There was 22.79 percent of the chamber upstream of the manifold, 57.44 percent of the chamber with manifold, and 19.77 percent of the chamber downstream of the manifold. Port-to-culvert-area ratio was 0.95. The 7 upstream ports in each wall had 3-ft-deep triangular floor recesses 15 by 15 ft and the 13 downstream ports had 3-ft-deep rectangular floor recesses 15 by 15 ft (Plate 16). Prototype installation would require lowering of the culvert, port manifold, and floor recesses 3 ft to el -53.0 with the chamber floor remaining at el -50.0. This change was simulated by pool adjustments in the model and was not fabricated in the model facility, but would be accomplished in the prototype structure between the filling and emptying valves.

Recommended design

27. Barge tow tests indicated that hawser forces were reduced and balanced in an upstream and downstream direction with the type 15 (recommended) design. Comparisons of filling and emptying characteristics were made with 24- (full), 18- (three-fourths), and 12- (half) barge tows having displacements of 60,480, 45,360, and 30,240 tons, respectively, as depicted in Plate 6. Data were collected for a range of lifts up to 18.4 ft. Plots of filling and emptying times versus valve time are presented in Plate 17 and plots of maximum hawser forces versus filling and emptying times for 1-, 2-, and 4-min valve times are plotted in Plates 18 and 19. Tabulated data are listed in Tables 6 and 7.

28. With the addition of floor recesses to the filling system, the jets from the ports interrupted the water surface in the chamber as shown in Photos 4a-4f. Comparison of Photos 3 and 4 shows the turbulence resulting with the type 1 design and the type 15 design. As

expected, the benefits in reduced and better balanced hawser forces obtained with the floor recesses in the type 15 (recommended) sidewall port manifold resulted in minor disturbances of the water-surface turbulence; however, the turbulence was considered to be satisfactory.

Pressures Throughout the Type 15 (Recommended) System

29. The filling and emptying system with the type 1 (original) intake and outlet manifolds and type 15 sidewall port manifold was designated the type 15 (recommended) system. Average pressures recorded throughout this system with a 4-min valve time, for the 18.4-ft design lift condition are listed in Tables 3 and 5. There were no adverse pressures in the system. Piezometer locations are shown in Plate 10.

Filling and Emptying Times and Overall Lock Coefficients

30. Hydraulic losses are usually greater in the model than in the prototype because of the increased hydraulic resistance that results due to the lesser Reynolds numbers of flow in the model. In a model of an outlet conduit, it is possible to shorten the length of the conduit or increase the slope of the conduit to compensate for this difference. However, this is not possible with a lock model. Experience with lock models built to a 1:25 scale with the culverts reproduced in smooth plastic has shown that the filling and emptying times of a sidewall port manifold system will be approximately 10 percent less in the prototype than those indicated by the model. This time advantage can be expected in the subject prototype lock. The filling and emptying times indicated by the model are plotted in Plate 17 and are approximately 10 percent greater than those to be expected with the prototype lock.

31. Overall lock coefficients (C_L) based on the filling and emptying data in Plate 17 were computed by the equation:

$$C_L = \frac{2A_L\left(\sqrt{H + d} - \sqrt{d}\right)}{A_c(T - Kt_v)\sqrt{2g}}$$

where

A_L = area of lock chamber, sq ft

H = initial lift, ft

d = measured overfill, ft

A_c = area of culverts, sq ft

T = filling or emptying time, sec

K = a constant

t_v = valve time, sec

g = acceleration due to gravity, ft/sec^2

The term $(T - Kt_v)$ is the lock filling and emptying time for the hypothetical case of instantaneous valve opening and can be obtained by extrapolation of data in Plate 17. The overall lock coefficients are 0.67 and 0.63, respectively, for normal filling and emptying operations subject to an 18.4-ft lift. With a reverse head of 14 ft, the coefficients are 0.67 for filling and 0.60 for emptying.

Reverse Head Operations

32. The maximum reverse head (2.1 ft) for the period of record and a 1-ft reverse head were model-tested even though these may occur less than 1 percent of the time. Plots of filling and emptying times versus valve times are shown in Plate 20. Maximum longitudinal hawser forces measured on an 18-barge tow at a 12-ft draft are plotted in Plate 21. Table 8 is a tabulation of filling and emptying characteristics. The outlets performed satisfactorily as an intake and the intake performed equally well as an outlet for the reverse head condition.

Recommended Valve Schedules for Barge Tow Operations

33. Study of the filling and emptying data revealed that for any size barge tow with a 12-ft draft or less, the following valve times,

based on the schedule in Plate 8, should be used to limit hawser forces to approximately 5 tons:

Head, ft	Valve Schedules, min	
	Filling	Emptying
Normal 1 to 7	2	2
7 to 18.4	4	4
Reverse 1 to 2.1	2	2

These valve operating schedules are recommended for the type 15 system developed for barge tow traffic.

Generalized Tests with Barge Tows

34. Generalized tests* were made with the type 15 (recommended) filling and emptying system for lifts of 20, 30, and 40 ft with a 24-barge tow at a 12-ft draft. The clearance beneath the bottom of the barge and floor of the lock chamber was varied from 8 to 38 ft. Similar tests were conducted for lifts of 20 and 30 ft with the same tow at a 9-ft draft. Plates 22 and 23 are plots of filling times for 5-, 7.5-, 10-, 12.5-, 15-, and 20-ton hawser force limits indicating the effects of clearance and lift variations. The filling and emptying times for normal valve operation for 20-, 30-, and 40-ft lifts are plotted in Plate 24. Hawser forces during all generalized emptying tests were consistently below hawsers measured during filling operations with a comparable valve speed.

35. As previously defined in paragraph 7, submergence is the difference in elevation between the lower pool and lock chamber floor. In general the greater the submergence, the faster is the permissible filling time. However, in many cases each foot of submergence provided is quite costly and the designer needs to know the minimum submergence at which satisfactory operation can be expected. Data from various

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* Funded by CWIS No. 31076 "Work Unit for Improved Criteria for Lock Design."

model studies indicate that the jets from the ports expand in an upward direction at the same rate as they expand horizontally. Thus, a clear space between the bottom of the barge tow using the lock and floor of the lock chamber is required to minimize direct action of the port jets against the bottom of the tow. In a 150-ft-wide lock designed for tows at a 9-ft draft and assuming a 30-ft lift and hawser force limit of 5 tons, it appears from data in Plate 23 that a submergence of 28 ft should be provided (9-ft draft plus 19-ft clearance under the tow, one half of the 38-ft port spacing). A filling time of 10.8 min will result and a valve time of 6 min would be selected (Plate 24). If a greater clearance and resulting submergence is provided, then permissible filling times will be shorter; but an increase in clear space under the tow of 100 percent (38-ft port spacing equivalent) will allow a decrease of only 11 percent to 9.6 min and a valve time of about 4 min. On the other hand, a 32 percent reduction in suggested clearance under the tow to 12 ft would increase permissible filling time about 9 percent to 11.8 min and would require a valve time of about 8 min.

36. Paragraphs 34 and 35 are included to permit lock designers sufficient input for evaluating the effect of clearance beneath barge tows for a well-designed sidewall port filling and emptying system in the 150-ft-wide lock chamber.

PART IV: SHIP TESTS AND RESULTS

Introduction

37. The type 15 (recommended) filling and emptying system developed for barge tows was identical with that developed for deep-draft ships except for the invert depth of the lock chamber and sidewall port manifold and floor recesses in the area of the manifolds. In lock chambers with sidewall port manifolds, the most serious disturbance is due to flow entering or leaving the chamber, which results in an oscillatory, longitudinal surging in the lock chamber during filling and emptying. This condition is very serious since the possibilities of damage to a barge tow or ship and lock structures are great. The larger the chamber and tow or ship, the more important it becomes to minimize the surging. In low-lift locks this can be accomplished by the following:

- a. Optimization of the sidewall port system. This was essentially accomplished with barge tows in developing the type 15 port arrangement.
- b. Valve scheduling, by slowing valve opening time, or reversing the valve to reduce overtravel or undertravel at the end of the filling or emptying operations.
- c. Increasing minimum submergence (depth) in the lock chamber and thereby increasing the clearance between the bottom of the tow or ship and the chamber floor.

Performance of the type 15 port arrangement and system and modifications required to maintain satisfactory hawser forces while handling a ship with a length of 900 ft, width of 140 ft, and depth of 55 ft (Plate 7) are discussed in subsequent paragraphs 38-51.

38. The MR-GO model ship displacements are four to five times greater than ship displacements previously investigated in lock models in the United States. Plate 25 graphically illustrates this increase by comparing the 27-ft-draft model ship with 36,990-ton displacement used in model tests of the 84-ft-wide Eisenhower Lock for the St. Lawrence Seaway Project and the 45-ft-draft deepwater ship with

171,000-ton displacement modeled in this investigation of the 150-ft-wide MR-GO lock.

39. Engineer Manual 1110-2-1604 (draft, April 1963), "Hydraulic Design of Navigation Locks," states the following:

> "At the present state of lock design, it is believed that a limiting hawser stress of approximately 1 ton per 5,000 tons of gross cargo should not be exceeded. Under very favorable conditions, it may be possible to design a lock hydraulic system that will produce no hawser stresses at all on craft in the lock; however, it is not essential that such ideal conditions be achieved, but the smoothest operation practicable should be sought. Most of the barge locks which have been model tested in the United States in recent years have been designed for a maximum hawser force of 4 to 5 tons on a tow of any size moored at random in the lock. A maximum hawser stress of 10 tons has been adopted for locks that handle primarily deep-draft ships."

Hawser Forces

Initial tests

40. The model ship was loaded to drafts of 30, 37.5, and 45 ft and filling operations were conducted with an 8-min valve time and 18.4-ft lift with minimum stage conditions (Plate 26). The unusually high longitudinal hawser forces increased directly from 10.5 tons with a 30-ft ship draft and 18.28-ft clearance to 31.5 tons with a 45-ft ship draft and 3.28-ft clearance. Clearance is defined as the distance between the bottom of the ship (or barge tow) and the floor of the lock chamber at lower pool stage.

41. The 37.5- and 45-ft ship drafts were selected for further testing with 1- to 18.4-ft lifts. Plates 27 and 28 are plots showing filling and emptying times required to keep hawser forces between 10- to 45-ton limits. Reference to Plate 17 will indicate valve times required to obtain the filling or emptying times in Plates 27 and 28.

Effect of ship moor-
ing and reversing valves

42. Plates 29 and 30 are traces of longitudinal hawser forces measured while using an 8-min valve schedule to fill and empty the lock. The top traces indicate the hawser force observed with a single longitudinal hawser force link attached to the ship at the upstream end. The second traces are the hawser forces observed with two longitudinal force links attached to the ship. The original link was maintained at the upstream end of the ship and a second link was installed downstream in such a manner that it reacted equal and opposite to the upstream link (tension versus compression) throughout the test. The two forces, when added together, approached that measured with the single link in the top trace, as was expected. In the third or lower illustration the two devices are again used but the valve is allowed to open only 7 min and then it is reversed. These data indicate that multiple prototype hawser mooring devices can be expected to reduce the maximum forces during both filling or emptying. Reversing the valve will reduce overtravel or undertravel and this is especially necessary during emptying with the system as developed to this point. Overtravel does not create a longitudinal hawser problem at the end of the filling operation comparable with that caused by emptying.

Effect of valve time

43. Plates 31 and 32 are traces of the single longitudinal force during filling and emptying tests, respectively, using 8-, 16-, and 20-min valve times and similar tests with these same valve times reversed at 7, 10.5, and 14 min. Examination of these traces indicates that a 20-min valve time will reduce the maximum longitudinal hawser force to 16 tons and will require 17.1 min to fill the lock. Similar tests for emptying (Plate 32) show that a 20-min valve time empties the lock in 18.1 min, but results in undertravel of 0.45 ft and maximum hawser forces of 25.7 tons at 20 min and 17.2 tons at 22.1 min. The tests of a 20-min valve schedule reversed at 14 min show an emptying time of 22 min with undertravel reduced to 0.05 ft and no problem with

longitudinal hawser force. Filling and emptying times of about 18 and 22 min, respectively, would be required to limit the hawser forces to 16 and 10 tons with a 20-min valve reversed at 14 min. Any filling operation with a partial valve opening would probably require an opening of the valve less than 5 percent and this is not feasible.

Effect of clearance beneath ship

44. When a ship is moored in the area of the sidewall port manifold at a draft which places the hull opposite the sidewall port manifold jets, turbulence created by the jets during filling must be dissipated against the ship hull and available clearance between the bottom of the ship and lock chamber floor. Plate 33 presents maximum longitudinal hawser forces versus filling and emptying times for 4-, 6-, and 8-min valve times with the model ship at 45-ft draft and clearances under the ship at minimum stage conditions of 3.28, 7.88, and 11.4 ft. These data simulate in effect lowering the sidewall port manifold and chamber floor in the type 15 system. There was no clearance problem for 12-ft draft barge tows due to the deep minimum submergence available.

45. During a conference between representatives of OCE, LMVD, LMN, LMK, and WES, test results, and particularly the ship model tests in paragraphs 37-44, were discussed. It was the consensus of the participants that the type 15 sidewall port system as developed was an excellent design for barge traffic, but the system was not adequate to limit the hawser forces to 10 tons with reasonable filling and emptying times for deep-draft ships. Thus tests were authorized to determine the effect of increasing clearance beneath the ship on longitudinal hawser forces and filling and emptying times with model ship drafts of 30.0, 37.5, and 45 ft. From these data, a determination could be made as to whether it would be more economical to lower the lock chamber and sidewall port manifold between the upper and lower miter gate sills or to consider a longitudinal floor culvert filling and emptying system.

46. After the conference mentioned above, Mr. J. P. Davis, consultant to OCE, recommended to OCE that the limiting hawser force criterion for ship traffic at MR-GO lock be increased to 20 tons since the 10-ton criterion for ships in the Lock Design Manual was

based on ships with drafts of 27-29 ft and displacements of only 37,000 tons. This recommendation was approved and the section of the Engineer Manual 1110-2-1604 "Hydraulic Design of Navigation Locks," which is being updated, concerned with hawser forces will include criteria for barge tows, single vessels up to 50,000 dwt, and single vessels greater than 50,000 dwt as follows:

Type Transportation	Limiting Hawser Forces Measured in Model
a. Barge tows	5 tons
b. Single vessels up to 50,000 dwt	10 tons
c. Single vessels greater than 50,000 dwt	May exceed 10 tons*

* Model tests indicate that if a filling and emptying system is designed to meet criteria a and b (above), the hawser force (measured in a model) will not exceed approximately 25 tons for vessels up to 170,000 dwt.

47. Plates 34-41 are plots of clearance versus filling or emptying times for 25- and 20-ton hawser force limits obtained with 45- and 37.5-ft ship drafts and 1.0- to 18.4-ft lifts. Similar plots for 10- and 20-ton hawser force limits with a 30-ft ship draft are shown in Plates 42 and 43. On these plots the position of original minimum clearance is shown as a solid horizontal line for each lift and appropriate valve times are ticked and labeled for ready reference. The data plotted in Plates 34-43 were selected from plots (similar to Plate 33) of the basic data as listed in Tables 9-14. Also, reference can be made to Plate 17 for a plot of filling and emptying times versus valve time for the type 15 (recommended) port arrangement. Table 1 presents clearances for the three ship drafts investigated for all lift and minimum stage conditions.

Recommended Valve Schedules

48. Table 15 is provided to assist in the economic evaluations

of lowering the chamber floor and sidewall port manifold between miter gates for ships. For ships with 45-, 37.5-, and 30-ft drafts, the valve time in minutes required to limit hawser forces between 10 and 25 tons during filling and emptying operations for 1.0- to 18.4-ft lifts at minimum stage, minimum stage +5 ft, and minimum stage +10 ft are tabulated. Naturally, the greater the clearance, the lesser the longitudinal hawser forces and number of valve speeds required. For example, during filling operations with a 37.5-ft ship draft and 10 ft of clearance added to minimum stage conditions by lowering the chamber, the table shows hawser forces could be limited to 25 tons by using a 1-min valve time up to a 2-ft lift, a 2-min valve time for 2- to 7-ft lifts, a 3-min valve time for 11- to 14-ft lifts, and a 4-min valve time for the 18.4-ft lift. Model data input of this type together with projected traffic requirements, lift and stage duration studies, and other pertinent considerations will permit necessary economic analyses to determine the feasibility of the type 15 (recommended) manifold port system as developed with some lowering of the chamber floor and manifolds between the miter gate sills.

49. Examination of the data in Table 15 without consideration of projected traffic requirements, lift and stage duration studies, and/or other pertinent data indicates that the type 15 sidewall port system as developed could be used with ships as large as 45-ft draft and 171,000-ton displacement with filling valve times from 2 to 12 min and emptying valve times of 2 to 7 min and still have maximum hawser forces of 25 tons. However, with the design lift of 18.4 ft and the minimum pool stage at el -2.5, the clearance is only 3.28 ft. As stated in paragraph 1, the lock structure is designed to mlg datum (zero mlg equals -0.78 ft msl). All river stages are in ft msl and are presented as msl stages. Therefore, a minimum lower pool stage of -2.5 msl is equal to -1.72 mlg and results in an available depth of 48.28 ft with the chamber floor at el -50 mlg; thus with a 45-ft draft, clearance is only 3.28 ft. It is considered that the system as designed for barge tows is adequate for ships with drafts and displacements up to 45 ft and 171,000 tons, respectively, providing 2- to 12-min valve

schedules are included in the culvert valve operating equipment and 25-ton hawser force is acceptable.

50. If the assumptions in paragraph 49 are not practicable, then the sidewall port manifolds and floor recesses could be lowered 5 ft to invert el -58.0 mlg and the chamber floor to invert el -55.0 mlg. This would permit safer operation of the system and valve selection to obtain maximum hawser forces of 25 tons by valve speeds between 1 and 8 min, or a maximum hawser force of 20 tons by valve speeds between 2 and 10 min for 1.0- to 18.4-ft lifts. Data are available to further refine the system should additional evaluation and economic studies indicate the need for considering additional alternatives.

51. The type 15 (recommended) sidewall port system as developed is considered optimum for barge tows and will be satisfactory for ships with the proper clearance provided between the bottom of the ships and the floor of the lock chamber. For the culvert size and sidewall port system selected, the optimum elements were developed from the model tests.

Freshwater Diversion

52. At a conference at WES on 13 February 1975 the MR-GO lock filling and emptying system model tests were discussed and results were presented to representatives from LMVD, LMN, LMK, and WES. The model was then placed in a suspended status by LMN and had remained in that status when this report was prepared. When the model tests were suspended, WES was requested to hold freshwater diversion tests in abeyance until site and system selection were finalized. The freshwater diversion plan utilizes lift differentials tabulated below with their corresponding upper and lower pool elevations.

Lift ft	Upper Pool ft msl	Lower Pool ft msl
1	1.0	0.0
2	2.0	0.0
4	4.0	0.0
8	8.0	0.0
12	12.0	0.0

For comparison purposes, model discharge and velocities of flow in the discharge channel for these differentials would be collected and tabulated to check design computations for freshwater diversion by the two methods described in the next paragraph.

53. Anytime the lock is not being operated for navigation it would be used to divert additional fresh water from the river. One condition would exist, for example, after a vessel had been locked into the Mississippi River (model headbay). In this case, the tailbay miter gate would remain closed. The forebay culvert valves would be closed and the tailbay culvert valves would be opened. For the other condition, after a vessel has been locked into the outlet area (model tailbay) the miter gates and culvert valves would be operated in reverse manner.

54. At the time the model was authorized the only lock facility available permitted construction of about 100 ft of channel downstream of the outlets. It is questionable whether velocities measured in this area with limited channel topography would be of reliable value for comparison purposes with prototype computations. The computed values would probably be more reliable.

PART V: DISCUSSION OF TESTS AND RESULTS

55. The proposed MR-GO lock will be used by both ship and barge traffic. The size of the lock is unprecedented in the United States. The filling and emptying system must perform satisfactorily for lifts up to 18.4 ft as well as with reverse heads up to 3 ft. The type 15 (recommended) system as developed in model tests is considered the optimum sidewall port system for barge tows and will be satisfactory for ship traffic with additional clearance provided between the bottom of ships and floor of the lock chamber.

56. Flow distribution was excellent through the ports of the intake and outlet manifolds. Rounding of the sharp corner of the upstream lock wall at sta 2+50.8U with a 10-ft radius will probably reduce or eliminate the occasional weak vortex tendency near the left wall intake.

57. No adverse pressures were observed in the recommended system during filling or emptying operations. Pressure cells installed immediately downstream of the right culvert filling valve indicated that minimum pressures were never over 6 ft below lower pool and were 23 ft above the roof of the culvert with design lift and stage conditions.

58. The type 15 sidewall port manifold system consisting of 20 ports, spaced 38 ft on centers, with ports staggered in opposite walls was satisfactory with respect to the size, spacing, position, number, and geometry of ports. Performance of the system was improved. by the addition of floor recesses in front of each port. Triangular recesses 15 by 15 by 3 ft deep were installed at the 7 upstream ports in each wall, and rectangular recesses 15 by 15 by 3 ft deep were installed at the 13 downstream ports in each wall. Prototype installation requires lowering of the culvert, sidewall port manifold, and floor recess inverts 3 ft to el -53.0. This port arrangement was designated type 15 and was recommended for barge tows. Barge tow tests with this system indicated balanced forces upstream and downstream and left and right for barge tows consisting of 24, 18, and 12 barges at various positions in the chamber. The following recommended valve

schedules for filling and emptying will limit hawser forces to approximately 5 tons.

Head, ft	Valve Schedules, min Filling	Emptying
Normal 1 to 7	2	2
7 to 18.4	4	4
Reverse 1 to 2.1	2	2

59. A time advantage of approximately 10 percent can be expected in the prototype lock over filling and emptying times indicated by the lock model in Plates 17, 20, and 43. Experience with 1:25-scale lock models of sidewall port systems with smooth plastic culverts indicates that hydraulic losses are usually about 10 percent greater in the model than in the prototype because of the increased hydraulic resistance that results due to the lesser Reynolds numbers of flow in the model.

60. The overall lock coefficients are 0.67 and 0.63, respectively, for normal filling and emptying operations for the design lift.

61. It is not feasible to have two systems, one for barge traffic and another for ship traffic. Thus for the system developed for barge traffic, it will be necessary to evaluate the ship model test results reported herein together with projected traffic requirements, head and stage duration history, and other pertinent considerations that will permit economic analysis to determine the feasibility of the type 15 (recommended) sidewall port system as developed with some lowering of the chamber, culvert, manifold, and floor recesses between the miter gates necessary to accommodate both barge and ship traffic.

62. The type 15 sidewall port system as developed is considered optimum for barge tows and will be satisfactory for ships with the additional clearance provided between the bottom of the ship and floor of the lock chamber. Table 15 presents the basis for this determination for clearance under the ship at minimum stage +5 and +10 ft for a range of lifts from 1.0 to 18.4 ft with ships at 45-, 37.5-, and 30-ft draft. Valve times required to limit hawser forces on the ship to 10, 20, and 25 tons are indicated for filling and emptying operations. Resulting filling and emptying times can be found in Plate 17.

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Table 1

Lifts and Minimum msl and mlg Stages with Minimum Depth Available with Chamber Floor at El -50.0 mlg; Resulting Clearance Under Ship to Chamber Floor with Draft of Ship 30, 37.5, and 45 ft; Adjusted mlg Stages Required to Simulate Chamber Floor at El -50.0 mlg and Invert of Culvert, Sidewall Ports, and Floor Recesses at El -53.0 mlg

Lift ft	Minimum msl Stages Upper Pool	Minimum msl Stages Lower Pool	Minimum mlg Stages Upper Pool	Minimum mlg Stages Lower Pool	Minimum Depth, ft, Available if Lock Floor Is -50.0 mlg	Clearance Under Ship When Draft Is 30 ft	Clearance Under Ship When Draft Is 37.5 ft	Clearance Under Ship When Draft Is 45 ft	Adjusted mlg Stages Required to Simulate Floor Recesses Raised 3 ft and Culvert Lowered 3 ft to el -53.0 mlg Upper Pool	Adjusted mlg Stages Required to Simulate Floor Recesses Raised 3 ft and Culvert Lowered 3 ft to el -53.0 mlg Lower Pool
					Normal Lifts					
18.4	15.9	-2.5	16.68	-1.72	48.28	18.28	10.78	3.28	19.68	1.28
16.0	16.0	0.8	17.68	1.58	51.58	21.58	14.08	6.58	20.68	4.58
15.0	15.2	0.2	15.98	0.98	50.98	20.98	13.48	5.98	18.98	3.98
14.0	12.7	-1.3	13.48	-0.52	49.48	19.48	11.98	4.48	16.48	2.48
13.0	12.6	-0.4	13.38	0.38	50.38	20.38	12.88	5.38	16.38	3.38
12.0	11.9	-0.1	12.68	0.68	50.68	20.68	13.18	5.68	15.68	3.68
11.0	10.9	-0.1	11.68	0.68	50.68	20.68	13.18	5.68	14.68	3.68
10.0	9.4	-0.6	10.18	0.18	50.18	20.18	12.68	5.18	13.18	3.18
9.0	8.4	-0.6	9.18	0.18	50.18	20.18	12.68	5.18	12.18	3.18
8.0	7.3	-0.7	8.08	0.08	50.08	20.08	12.58	5.08	11.08	3.08
7.0	6.6	-0.4	7.38	0.38	50.38	20.38	12.88	5.38	10.38	3.38
6.0	5.4	-0.6	6.18	0.18	50.18	20.18	12.68	5.18	9.18	3.18
5.0	4.8	-0.2	5.58	0.58	50.58	20.58	13.08	5.58	8.58	3.58
4.0	3.6	-0.4	4.38	0.38	50.38	20.38	12.88	5.38	7.38	3.38
3.0	2.0	-1.0	2.78	-0.22	49.78	19.78	12.28	4.78	5.78	2.78
2.0	1.2	-0.8	1.98	-0.02	49.98	19.98	12.48	4.98	4.98	2.98
1.0	0.4	-0.5	1.18	0.18	50.18	20.18	12.68	5.18	4.18	3.18
					Reverse Heads					
2.1	5.1	3.0	5.88	3.70	53.78	23.78	16.28	8.78	8.88	6.78
1.5	3.0	1.5	3.78	2.28	52.28	22.28	14.78	7.28	6.78	5.28
1.0	0.5	-0.5	1.28	0.28	50.23	20.28	12.78	5.28	4.28	3.28

Note: msl - mean sea level
mlg - mean low gulf datum (zero mlg = -0.78 ft, msl)

Table 2

Average Pressures in Type 1 (Original) Filling System, Steady-Flow Conditions; Discharge 8075 cfs per Culvert; Filling Valves and Lower Miter Gates Fully Open; Upper Miter Gates and Emptying Valves Closed; Upper Pool El +15.9, Lower Pool El +3.6

Piezometer No.	Piezometer Station	Piezometer Elevation	Reading	Pressure
Left Wall Intake Piezometer, Group A				
Port 1	2+22.80U	-50.0	14.2	64.2
2	2+20.80U	-50.0	13.7	63.7
3	2+06.30U	-50.0	13.1	63.1
4	1+92.00U	-50.0	12.3	62.3
5	1+78.80U	-50.0	11.3	61.3
6	1+64.30U	-50.0	10.3	60.3
7	1+47.80U	-50.0	9.5	59.5
8	1+34.80U	-50.0	8.1	58.1
Pickup 9	2+08.30U	-50.0	13.1	63.1
10	1+93.80U	-50.0	12.1	62.1
11	1+80.00U	-50.0	11.2	61.2
12	1+65.30U	-50.0	10.3	60.3
13	1+50.80U	-50.0	9.3	59.3
14	1+35.80U	-50.0	8.4	58.4
15	0+78.00U	-50.0	7.6	57.6
Left Wall Filling Valve Piezometers, Group B				
Ring 1	1+23.50D	-50.0	6.2	56.2
2	1+23.50D	-40.75	6.3	47.05
3	1+23.50D	-31.5	6.4	37.9
4	1+23.50D	-40.75	6.5	56.5
5	1+66.75D	-31.5	5.5	37.0
6	1+70.75D	-31.5	5.6	37.1
7	1+74.75D	-31.5	5.8	37.3
8	1+78.75D	-31.5	5.7	37.2
9	1+82.75D	-31.5	5.8	37.3
10	1+86.75D	-31.5	5.8	37.3
11	1+90.75D	-31.5	5.8	37.3

(Continued)

Note: Upper and lower pool stages in ft msl. Piezometer zero and reading in ft mlg (zero mlg = 0.78 ft msl). Pressures are in prototype feet of water.

Table 2 (Concluded)

Piezometer No.	Station	Elevation	Reading	Pressure
Left Wall Filling Valve Piezometers, Group B (Continued)				
12	2+00.50D	-31.5	5.8	37.3
13	2+05.50D	-31.5	5.7	37.2
14	2+10.50D	-31.5	5.7	37.2
15	2+60.50D	-31.5	5.6	37.1
Left Wall Culvert Piezometers, Group C				
1	2+75.00D	-40.75	5.3	46.05
2	4+27.00D	-40.75	6.8	47.55
3	5+79.00D	-40.75	8.2	48.95
7	7+31.00D	-40.75	9.4	50.15
9	8+83.00D	-40.75	10.2	50.95
11	10+35.00D	-40.75	10.4	51.15

Table 3

Average Piezometer Reading During Filling Operation, Type 15 Port Arrangement, 18.4-ft Design Lift, Upper Pool El 15.9, Lower Pool El -2.5

Piezometer Locations			Average Piezometer Readings in Prototype Feet of Water																	
No.	Station	Elevation	*T = 30 **LC = -2.5	T = 60 LC = -2.2	T = 90 LC = -2.0	T = 120 LC = -1.0	T = 150 LC = 0.2	T = 180 LC = 1.7	T = 210 LC = 3.5	T = 240 LC = 5.0	T = 270 LC = 7.2	T = 300 LC = 9.0	T = 360 LC = 12.0	T = 420 LC = 14.0	T = 480 LC = 15.5	T = 540 LC = 16.4	T = 600 LC = 16.5	T = 660 LC = 16.4	T = 720 LC =	T = 800 LC =
									Left Wall Intake Piezometers, Group A											
Port 1	2+22.80U	-50.0	15.9	15.9	15.5	15.0	14.9	14.4	14.0	13.9	14.0	14.2	15.0	15.2	15.5	15.8	15.8	15.9	--	--
2	2+20.80U	-50.0	15.9	15.9	15.5	15.0	14.8	14.3	13.8	13.6	13.7	14.0	14.8	15.1	15.5	15.8	15.9	15.9	--	--
3	2+06.30U	-50.0	15.9	15.8	15.4	14.9	14.5	13.7	13.0	13.0	13.0	13.5	14.5	15.0	15.5	15.8	16.0	15.9	--	--
4	1+92.00U	-50.0	15.9	15.8	15.4	14.8	14.1	13.1	12.5	12.2	12.5	13.0	14.1	15.0	15.5	15.8	16.0	15.9	--	--
5	1+78.80U	-50.0	15.8	15.8	15.2	14.5	13.5	12.6	12.0	11.5	12.0	12.5	13.9	15.0	15.5	15.8	15.9	15.9	--	--
6	1+64.30U	-50.0	15.8	15.8	15.0	14.2	13.2	12.0	11.4	11.1	11.5	12.0	13.5	14.6	15.4	15.8	16.0	15.9	--	--
7	1+47.80U	-50.0	15.8	15.8	15.0	14.2	13.0	11.6	10.5	10.0	10.5	11.3	13.0	14.5	15.4	15.8	16.0	15.9	--	--
8	1+34.80U	-50.0	15.7	15.4	14.8	13.5	12.2	10.6	9.2	8.7	9.5	10.5	12.6	14.1	15.2	15.8	16.0	15.9	--	--
Pickup 9	2+08.30U	-50.0	15.8	15.8	15.5	15.0	14.4	13.6	13.0	13.0	13.0	13.5	14.2	15.0	15.5	15.8	16.0	15.9	--	--
10	1+93.80U	-50.0	15.8	15.8	15.1	14.8	13.9	13.0	12.3	12.0	12.5	13.0	14.0	15.0	15.4	15.8	16.0	15.9	--	--
11	1+80.00U	-50.0	15.8	15.8	15.0	14.5	13.5	12.5	11.8	11.2	11.9	12.5	13.8	14.8	15.4	15.8	16.0	15.9	--	--
12	1+65.30U	-50.0	15.8	15.8	14.9	14.1	13.2	12.0	11.0	10.6	11.0	12.0	13.5	14.7	15.3	15.8	16.0	15.9	--	--
13	1+50.80U	-50.0	15.8	15.5	14.9	13.9	12.8	11.3	10.0	10.0	10.4	11.4	13.0	14.5	15.3	15.8	16.0	15.9	--	--
14	1+35.80U	-50.0	15.7	15.4	14.9	13.7	12.4	10.8	9.6	9.0	9.9	10.9	12.9	15.5	15.3	15.8	16.0	15.9	--	--
15	0+78.00	-50.0	15.2	15.0	14.3	13.0	11.8	10.0	8.7	8.3	9.4	10.7	12.8	14.5	15.4	15.8	16.0	15.9	--	--
									Left Wall Filling Valve Piezometers, Group B											
Ring 1	1+23.50D	-50.0	14.5	14.5	13.8	12.2	10.8	9.0	7.4	7.5	8.7	10.0	12.7	14.5	15.6	16.0	16.2	15.9	--	--
2	1+23.50D	-40.75	14.5	14.5	13.8	12.2	10.8	9.0	7.4	7.5	8.7	10.0	12.6	14.5	15.6	16.0	15.1	15.9	--	--
3	1+23.50D	-31.50	14.4	14.5	13.8	12.3	10.8	9.0	7.4	7.7	8.8	10.2	12.5	14.5	15.5	16.0	15.1	15.9	--	--
4	1+23.50D	-40.75	14.3	14.5	13.8	12.2	10.8	8.8	7.4	7.3	8.5	10.0	12.5	14.5	15.5	16.0	15.1	15.9	--	--
5	1+68.75D	-31.50	-2.9	-4.5	-5.8	-6.5	-6.0	-4.0	-0.5	3.5	8.0	10.0	12.2	14.1	15.5	16.0	16.1	16.0	--	--
6	1+70.75D	-31.50	-2.9	-4.5	-5.7	-6.8	-6.3	-5.0	-1.2	4.0	8.0	10.0	12.2	14.1	15.4	16.0	16.1	16.0	--	--
7	1+74.75D	-31.50	-2.9	-4.5	-6.0	-6.8	-6.0	-4.5	-0.5	6.0	8.0	10.0	12.2	14.1	15.5	16.0	16.2	16.0	--	--
8	1+78.75D	-31.50	-2.9	-4.5	-6.0	-6.8	-6.3	-4.0	0.0	6.3	8.0	10.0	12.2	14.1	15.7	16.0	16.2	16.0	--	--
9	1+82.75D	-31.50	-2.9	-4.5	-6.0	-6.8	-6.2	-3.0	0.5	6.5	8.0	10.0	12.2	14.1	15.6	16.0	16.2	16.0	--	--
10	1+86.75D	-31.50	-2.9	-4.5	-6.0	-6.8	-6.0	-3.5	2.0	6.5	8.0	10.0	12.2	14.1	15.6	16.0	16.2	16.0	--	--
11	1+90.75D	-31.50	-2.8	-4.6	-6.0	-6.7	-6.0	-3.1	2.5	6.3	8.0	10.0	12.2	14.1	15.6	16.0	16.2	16.0	--	--
12	2+00.50D	-31.50	-2.1	-5.0	-5.8	-6.1	-5.0	-1.5	3.5	6.4	8.0	10.0	12.2	14.1	15.6	16.0	16.2	16.0	--	--
13	2+05.50D	-31.50	-2.1	-5.0	-5.5	-5.8	-5.0	-0.5	4.0	6.2	8.0	10.0	12.2	14.1	15.6	16.0	16.2	16.0	--	--
14	2+10.50D	-31.50	-2.1	-5.0	-5.3	-5.0	-4.5	0.0	4.5	6.2	8.0	9.9	12.2	14.1	15.6	16.0	16.2	16.0	--	--
15	2+20.50D	-31.50	-2.1	-5.0	-5.1	-4.3	-3.5	0.1	4.5	6.3	8.0	10.0	12.2	14.1	15.6	16.0	16.2	16.0	--	--
									Left Wall Culvert Piezometer, Group C											
1	2+75.00D	-40.75	-2.1	-1.5	-1.0	0.0	1.0	3.0	5.0	7.0	8.4	10.0	12.5	14.5	15.7	16.2	16.2	16.1	--	--
3	4+27.00D	-40.75	-2.5	-1.5	-0.8	0.2	2.0	4.0	6.0	8.0	9.8	11.0	13.1	15.0	16.0	16.3	16.4	16.2	--	--
5	5+79.00D	-40.75	-2.5	-1.8	-1.1	0.2	2.2	4.5	7.0	9.0	10.9	12.0	14.0	15.5	16.1	16.5	16.5	16.3	--	--
7	7+31.00D	-40.75	-2.5	-2.1	-1.4	0.0	2.0	4.0	7.2	9.5	11.5	12.8	14.2	15.7	16.3	16.7	16.8	16.5	--	--
9	8+83.00D	-40.75	-2.5	-2.3	-1.5	0.0	2.0	4.0	7.2	10.0	12.0	13.3	14.7	15.9	16.5	16.8	16.7	16.5	--	--
11	10+35.00D	-40.75	-2.5	-2.5	-1.5	0.0	2.0	4.0	7.1	10.0	12.0	13.3	14.6	15.8	16.5	16.7	16.7	16.5	--	--

Note: Lock filled in 8.1 min with 4-min valve.
* T denotes time (in prototype seconds) after beginning of movement of valve.
** LC denotes elevation of water surface in lock chamber.
Upper and lower pool stages in ft msl.
Piezometer zero and reading in ft mlg (zero mlg = -0.78 ft msl).

Table 4

Average Pressures in Type 1 (Original) Emptying System, Steady-Flow Conditions; Discharge 6850 cfs per Culvert; Emptying Valves And Upper Miter Gates Fully Open; Lower Miter Gates and Filling Valves Closed; Upper Pool El +13.33, Lower Pool El -2.5

Piezometer No.	Piezometer Station	Piezometer Elevation	Piezometer Reading	Pressure
	Left Wall Culvert Piezometers, Group C			
2	3+51.00D	-40.75	10.0	50.75
4	5+03.00D	-40.75	9.2	49.95
6	6+55.00D	-40.75	7.9	48.65
8	8+07.00D	-40.75	7.4	48.15
10	9+59.00D	-40.75	-0.4	40.35
12	11+11.00D	-40.75	-4.7	36.05
	Left Wall Emptying Valve Piezometers, Group D			
Ring 1B	11+57.00D	-50.0	-5.0	45.0
2L	11+57.00D	-40.75	-5.0	35.75
3T	11+57.00D	-31.50	-5.0	26.5
4R	11+57.00D	-40.75	-5.0	35.75
5	12+06.50D	-31.50	-6.3	25.2
6	12+10.50D	-31.50	-6.2	25.3
Ring 7B	12+14.50D	-50.00	-6.2	43.8
8L	12+14.50D	-40.75	-6.2	34.55
9T	12+14.50D	-31.50	-6.0	25.5
10R	12+14.50D	-40.75	-6.0	34.75
11	12+18.50D	-31.50	-6.1	25.4
12	12+22.50D	-31.50	-6.1	25.4
13	12+34.00D	-31.50	-6.3	25.2
14	12+38.00D	-31.50	-6.3	25.2
15	13+27.50D	-50.00	-7.3	42.7
	Left Wall Outlet Manifold Piezometers, Group E			
1	14+00.00D	-50.00	-8.0	42.0
2	14+79.61D	-50.00	-3.3	46.7
3	14+86.61D	-50.00	-2.0	48.0

(Continued)

Note: Upper and lower pool stages in ft msl. Piezometer zero and reading in ft mlg (zero mlg = -0.78 ft msl). Pressures are in prototype feet of water.

Table 4 (Concluded)

Piezometer No.	Station	Elevation	Reading	Pressure
Left Wall Outlet Manifold Piezometers, Group E (Continued)				
4	15+04.61D	-50.0	-2.7	47.3
5	15+23.61D	-50.0	-3.2	46.8
6	15+42.61D	-50.0	-3.8	46.2
7	15+47.61D	-50.0	-4.3	45.7
8	14+90.00D	-50.0	-3.7	46.3
9	15+07.00D	-50.0	-4.4	45.6
10	15+28.00D	-50.0	-4.9	45.1

Table 5

Average Piezometer Readings During Emptying Operation, Type 15 Port Arrangement, 18.4-ft Design Lift, Upper Pool El 15.9, Lower Pool El -2.5

Piezometer Location			Average Piezometer Reading in Prototype Ft of Water																	
No.	Station	Elevation	*T = 30 **LC = 15.0	T = 60 LC = 15.7	T = 90 LC = 15.0	T = 120 LC = 14.4	T = 150 LC = 13.3	T = 180 LC = 11.7	T = 210 LC = 10.0	T = 240 LC = 8.1	T = 270 LC = 6.5	T = 300 LC = 1.7	T = 360 LC = 1.9	T = 420 LC = -0.3	T = 480 LC = -1.9	T = 540 LC = -2.8	T = 600 LC = -3.2	T = 660 LC = -3.0	T = 720 LC =	T = 780 LC =
									Left Wall Culvert Piezometers, Group C											
2	3+31.00D	-40.75	16.0	15.7	15.0	14.0	12.3	10.0	7.5	5.5	3.8	2.4	0.3	-1.8	-2.2	-3.0	-3.3	-3.0	-2.8	-2.5
4	5+03.00D	-40.75	16.0	15.7	14.9	13.6	11.8	9.4	7.0	4.8	3.4	2.0	0.0	-1.3	-2.2	-3.0	-3.2	-3.0	-2.7	-2.4
6	6+55.00D	-40.75	16.0	15.6	14.5	13.0	11.0	8.4	6.0	3.8	2.4	1.2	-0.5	-1.5	-2.5	-3.0	-3.2	-3.0	-2.7	-2.4
8	8+07.00D	-40.75	16.0	15.1	13.8	12.1	9.8	6.8	4.0	2.0	1.8	0.0	-1.2	-2.0	-2.5	-3.0	-3.0	-2.9	-2.7	-2.4
10	9+59.00D	-40.75	15.4	14.5	12.8	10.6	7.5	4.0	1.0	-1.0	-2.2	-2.2	-2.5	-2.6	-2.8	-3.0	-3.0	-2.8	-2.7	-2.4
12	11+11.00D	-40.75	14.5	14.0	12.0	9.5	6.0	2.4	-0.8	-2.6	-3.0	-3.1	-3.0	-2.8	-2.7	-2.8	-2.9	-2.7	-2.7	-2.5
									Left Wall Emptying Valve Piezometers, Group D											
Ring 1	11+57.00D	-50.00	14.4	13.9	11.8	9.2	5.7	2.0	-1.0	-2.8	-3.2	-3.3	-3.0	-2.7	-2.7	-2.7	-2.8	-2.7	-2.7	-2.5
2	11+57.00D	-40.75	14.3	13.9	11.8	9.1	5.7	2.0	-1.0	-2.8	-3.1	-3.3	-3.0	-2.7	-2.7	-2.7	-2.8	-2.7	-2.7	-2.5
3	11+57.00D	-31.50	14.3	13.8	11.8	9.1	5.7	2.0	-1.0	-2.9	-3.1	-3.2	-3.0	-2.7	-2.7	-2.7	-2.8	-2.7	-2.7	-2.5
4	11+57.00D	-40.75	14.3	13.9	11.8	9.1	5.7	1.9	-1.1	-2.9	-3.4	-3.3	-3.0	-2.8	-2.7	-2.7	-2.8	-2.7	-2.7	-2.5
5	12+06.50D	-31.50	-2.8	-5.4	-7.1	-9.0	-10.8	-10.2	-8.5	-6.5	-4.1	-3.8	-3.5	-3.0	-2.8	-2.7	-2.7	-2.6	-2.7	-2.5
6	12+10.50D	-31.50	-2.8	-5.4	-7.0	-9.0	-10.9	-10.8	-8.8	-5.2	-3.8	-3.5	-3.3	-3.0	-2.9	-2.8	-2.8	-2.8	-2.8	-2.7
Ring 7	12+14.50D	-50.00	-2.7	-5.2	-7.0	-8.6	-9.8	-9.0	-6.8	-4.5	-4.0	-3.8	-3.5	-3.0	-2.9	-2.8	-2.9	-2.9	-2.9	-2.7
8	12+14.50D	-40.75	-3.0	-5.1	-7.0	-8.6	-10.2	-10.0	-7.0	-4.5	-3.9	-3.8	-3.5	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-2.8
9	12+14.50D	-31.50	-3.1	-5.2	-7.0	-9.0	-10.7	-10.5	-8.7	-4.1	-3.7	-3.6	-3.3	-3.0	-2.7	-2.7	-2.8	-2.8	-2.8	-2.5
10	12+14.50D	-40.75	-3.1	-5.2	-7.0	-8.7	-10.5	-10.0	-7.5	-4.5	-3.7	-3.6	-3.3	-2.8	-2.6	-2.7	-2.8	-2.7	-2.7	-2.5
11	12+18.50D	-31.50	-3.1	-5.2	-7.2	-9.0	-10.5	-10.4	-7.8	-4.0	-3.7	-3.6	-3.3	-3.0	-2.7	-2.7	-2.8	-2.7	-2.7	-2.6
12	12+22.50D	-31.50	-3.1	-5.2	-7.4	-9.0	-10.5	-10.1	-7.2	-4.0	-3.8	-3.6	-3.3	-3.0	-3.0	-3.0	-3.0	-3.0	-2.9	-2.7
13	12+34.50D	-31.50	-2.2	-5.2	-7.4	-9.0	-10.1	-8.7	-4.8	-4.0	-3.9	-3.6	-3.3	-3.0	-2.7	-2.6	-2.8	-2.7	-2.7	-2.6
14	12+38.50D	-31.50	-2.0	-5.0	-7.4	-9.0	-9.9	-8.2	-4.0	-4.0	-3.9	-3.6	-3.3	-2.9	-2.7	-2.7	-2.8	-2.7	-2.7	-2.5
15	13+27.50D	-50.00	-2.0	-5.1	-2.2	-2.8	-3.2	-3.9	-4.1	-4.5	-4.2	-4.0	-3.4	-2.9	-2.7	-2.7	-2.8	-2.7	-2.7	-2.5
									Left Wall Outlet Manifold Piezometers, Group E											
1	14+00.00D	-50.00	-2.5	-2.2	-2.3	-2.0	-3.2	-4.0	-4.5	-4.6	-4.5	-4.1	-3.4	-3.0	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7
2	14+79.61D	-50.00	-2.5	-2.1	-2.0	-2.0	-2.1	-2.2	-2.4	-2.8	-2.3	-2.3	-2.3	-2.3	-2.4	-2.5	-2.5	-2.7	-2.7	-2.7
3	14+86.61D	-50.00	-2.6	-2.5	-2.4	-2.2	-2.1	-2.0	-2.0	-2.0	-1.8	-2.0	-2.0	-2.0	-2.4	-2.6	-2.5	-2.7	-2.7	-2.7
4	15+04.61D	-50.00	-2.6	-2.5	-2.4	-2.3	-2.5	-2.5	-2.2	-2.3	-2.2	-2.3	-2.2	-2.2	-2.4	-2.5	-2.6	-2.7	-2.7	-2.7
5	15+23.61D	-50.00	-2.5	-2.3	-2.1	-2.1	-2.0	-2.5	-2.3	-2.1	-2.0	-2.2	-2.0	-2.0	-2.3	-2.5	-2.6	-2.7	-2.7	-2.7
6	15+41.61D	-50.00	-2.5	-2.5	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.5	-2.5	-2.4	-2.4	-3.4	-2.5	-2.4	-2.7	-2.7	-2.7
7	15+47.61D	-50.00	-2.5	-2.5	-2.4	-2.3	-2.3	-2.3	-2.5	-2.8	-3.0	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.7	-2.7	-2.7
8	14+90.00D	-50.00	-2.4	-2.2	-2.1	-2.1	-2.3	-2.3	-2.5	-2.5	-2.5	-2.5	-2.4	-2.4	-2.5	-2.4	-2.4	-2.7	-2.7	-2.7
9	15+07.00D	-50.00	-2.4	-2.2	-2.0	-2.0	-2.3	-2.3	-2.7	-2.6	-2.8	-2.5	-2.4	-2.4	-2.4	-2.4	-2.4	-2.7	-2.7	-2.7
10	15+28.00D	-50.00	-2.4	-2.5	-2.5	-2.5	-2.3	-2.3	-2.7	-2.8	-3.0	-2.5	-2.5	-2.5	-2.5	-2.5	-2.4	-2.7	-2.7	-2.7

Note: Lock empties in 8.7 min with 4-min valve.
* T denotes time (in prototype seconds) after beginning of movement of valves.
** LC denotes elevation of water surface in lock chamber.
Upper and lower pool stages in ft msl.
Piezometer zero and reading in ft mlg (zero mlg = -0.78 ft msl).

Table 6

Filling Characteristics, Type 15 Port Arrangement, Generalized Tests with Barge Tow

						Maximum Hawser Forces															
					Filling or Emptying	Longitudinal				Upstream Transverse				Downstream Transverse							
						Upstream		Downstream		Left		Right		Left		Right					
No. of Barges	Lift ft	Upper Pool Stage ft	Lower Pool Stage ft	Valve Time min	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min				
24 Centered	18.4	15.9	-2.5	1	6.6	16.1	1.1	16.2	1.8	3.0	2.2	1.3	2.0	3.0	3.3	3.0	1.9				
				2	7.1	9.4	1.1	8.8	0.5	3.4	3.3	2.0	4.6	3.0	3.6	3.0	2.7				
				3	7.6	7.0	1.1	6.9	3.0	2.5	2.8	1.4	1.6	2.8	2.7	3.0	3.0				
				4	8.1	4.9	1.2	5.0	4.0	2.4	3.5	1.0	3.2	2.8	3.4	2.9	4.0				
	14.0	12.7	-1.3	1	5.7	14.2	1.1	16.2	0.8	2.4	1.9	1.2	2.4	2.0	1.8	3.0	0.4				
				2	6.2	8.0	1.2	9.0	0.6	2.0	3.0	1.0	4.1	2.0	2.4	1.6	4.7				
				3	6.7	5.8	1.2	5.2	0.5	2.4	3.1	1.2	1.3	2.4	3.4	2.0	2.9				
				4	7.2	4.2	1.3	4.2	1.9	1.8	5.8	1.8	5.9	2.4	5.1	2.7	5.0				
	11.0	10.9	-0.1	1	5.0	12.5	1.0	12.8	1.8	1.7	4.1	1.0	2.5	1.8	3.3	1.7	0.5				
				2	5.5	7.3	1.1	6.8	0.5	1.0	3.8	1.0	3.7	1.4	4.3	1.5	2.3				
				4	6.5	3.8	1.3	4.0	0.6	1.2	5.0	1.0	6.0	1.3	3.3	1.3	5.6				
	7.0	6.6	-0.4	1	3.9	10.7	1.0	9.6	1.8	1.4	1.5	1.0	1.5	1.7	1.8	1.6	0.5				
				2	4.4	5.8	1.3	5.6	0.5	1.0	2.8	1.0	3.5	1.7	2.4	1.2	1.9				
				4	5.4	3.0	1.4	2.8	0.5	1.0	4.3	1.0	4.5	1.6	3.5	1.0	3.6				
	5.0	4.8	-0.2	1	3.2	9.0	1.3	7.5	1.8	1.0	1.0	1.0	2.4	1.5	1.5	1.2	1.6				
				2	3.7	4.8	1.3	4.7	0.5	1.0	0.4	1.0	0.3	1.7	2.8	1.0	2.7				
				4	4.7	2.5	1.4	2.8	0.6	1.0	3.4	1.0	3.3	1.7	3.8	1.2	3.7				
	3.0	2.0	-1.0	1	2.5	7.2	1.3	5.0	1.8	1.0	1.0	1.0	1.2	1.2	2.3	1.0	2.6				
				2	3.0	3.9	1.3	3.6	0.5	1.0	0.2	1.0	2.7	1.0	2.7	1.0	2.8				
				4	4.0	1.6	1.4	2.2	0.6	1.0	2.6	1.0	4.2	1.0	0.4	1.0	2.0				
	2.0	1.2	-0.8	1	2.0	6.1	1.2	4.3	1.8	1.0	0.3	1.0	2.0	1.0	0.5	1.0	2.0				
				2	2.5	3.4	1.3	2.6	0.7	1.0	0.3	1.0	2.3	1.0	2.0	1.0	2.3				
				4	3.5	1.7	2.5	1.9	0.8	1.0	3.0	1.0	3.1	1.0	2.8	1.0	3.0				
	1.0	0.4	-0.6	1	1.5	4.6	1.3	3.7	1.8	1.0	1.3	1.0	1.0	1.0	0.5	1.0	0.9				
				2	2.0	2.6	1.3	2.3	0.6	1.0	1.2	1.0	1.6	1.0	1.4	1.0	1.8				
				4	3.0	1.6	2.5	1.3	0.7	1.0	2.5	1.0	2.7	1.0	1.8	1.0	1.6				

(Continued)

Note: Time listed under hawser forces is time of occurrence after beginning of movement of culvert valve. The 24-barge tow at 12-ft draft has a displacement of 60,480 tons.

Table 6 (Continued)

No. of Barges	Lift ft	Upper Pool Stage ft	Lower Pool Stage ft	Valve Time min	Filling or Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream Pull tons	Upstream Time min	Downstream Pull tons	Downstream Time min	Upstream Transverse: Left Pull tons	Left Time min	Right Pull tons	Right Time min	Downstream Transverse: Left Pull tons	Left Time min	Right Pull tons	Right Time min
18 Centered	18.4	15.9	-2.5	1	6.6	13.0	1.2	13.0	1.8	2.5	2.3	1.3	3.3	3.5	3.5	2.9	2.9
				2	7.1	6.9	1.1	6.7	2.9	2.6	4.0	1.1	1.5	2.1	1.9	2.5	2.8
				3	7.6	5.4	1.2	5.0	0.5	2.0	4.4	1.5	4.6	2.5	2.9	1.3	6.2
				4	8.1	3.9	1.2	3.8	0.5	2.5	3.9	1.0	4.8	3.5	3.4	2.0	4.5
	14.0	12.7	-1.3	1	5.7	9.8	1.1	9.0	1.7	3.0	3.5	1.0	4.6	4.0	3.2	1.8	3.7
				2	6.2	6.2	1.1	6.2	3.0	2.8	3.8	1.0	2.7	3.1	4.1	1.8	3.3
				3	6.7	4.8	1.1	4.9	2.9	2.0	4.0	1.0	3.9	2.8	3.7	1.6	3.9
				4	7.2	2.9	1.3	3.2	0.5	1.8	4.0	1.0	3.9	2.3	3.4	1.6	3.9
	11.0	10.9	-0.1	1	5.0	8.2	1.2	7.1	0.5	1.9	2.8	1.0	3.0	3.0	4.0	2.1	2.7
				2	5.5	5.2	1.1	4.9	0.5	1.7	3.0	1.0	3.9	2.0	3.7	1.7	3.6
				3	6.0	3.9	1.1	3.8	4.0	2.0	2.1	1.3	2.4	2.6	2.2	2.1	2.9
				4	6.5	2.6	1.3	2.7	0.5	1.3	0.5	1.0	5.9	2.5	2.9	1.7	4.4
	7.0	6.6	-0.4	1	3.9	7.2	1.2	5.3	1.7	1.2	2.7	1.7	2.3	2.0	3.1	1.6	3.0
				2	4.4	3.8	1.2	4.0	0.5	1.4	1.4	1.0	3.5	2.0	4.2	2.0	4.1
				3	4.9	2.8	1.2	3.1	0.5	1.0	4.1	1.0	3.6	2.2	3.4	1.7	3.2
				4	5.4	2.0	1.2	2.6	0.5	1.2	2.3	1.0	3.2	1.6	4.5	1.5	4.0
	5.0	4.8	-0.2	1	3.2	6.4	1.2	4.8	1.8	1.2	2.9	1.0	2.3	2.3	2.5	1.0	3.1
				2	3.7	3.5	1.2	3.4	0.5	1.0	2.6	1.0	2.7	2.2	2.3	1.0	2.4
				3	4.2	2.7	1.2	2.8	0.7	1.0	3.0	1.0	4.1	2.0	3.0	1.0	3.9
				4	4.7	2.0	1.2	2.0	0.5	1.8	4.0	1.0	4.5	2.3	4.1	1.0	4.2
	3.0	2.0	-1.0	1	2.5	5.5	1.2	3.5	0.7	1.0	2.4	1.0	2.7	1.4	2.0	1.0	2.1
				2	3.0	3.1	1.3	2.5	0.7	1.0	2.4	1.0	1.5	1.3	2.9	1.0	2.8
				3	3.5	2.0	1.2	2.0	0.5	1.0	1.4	1.0	1.3	1.2	2.9	1.0	2.4
				4	4.0	1.3	1.4	1.4	0.5	1.0	3.1	1.0	3.0	1.0	2.0	1.0	2.1

(Continued)

Note: Time listed under hawser forces is time of occurrence after beginning of movement of culvert valve. The 24-barge tow at 12-ft draft has a displacement of 60,480 tons. The 18-barge tow at 12-ft draft has a displacement of 45,360 tons.

(Sheet 2 of 4)

Table 6 (Continued)

No. of Barges	Lift ft	Upper Pool Stage ft	Lower Pool Stage ft	Valve Time min	Filling or Emptying Time min	Longitudinal Upstream Pull tons	Longitudinal Upstream Time min	Longitudinal Downstream Pull tons	Longitudinal Downstream Time min	Upstream Transverse Left Pull tons	Upstream Transverse Left Time min	Upstream Transverse Right Pull tons	Upstream Transverse Right Time min	Downstream Transverse Left Pull tons	Downstream Transverse Left Time min	Downstream Transverse Right Pull tons	Downstream Transverse Right Time min
18 Centered	2.0	1.2	-0.8	1	2.0	3.7	1.2	3.3	0.4	1.0	1.4	1.0	1.5	1.0	1.3	1.0	1.6
				2	2.5	2.2	1.3	2.3	0.7	1.0	1.8	1.0	2.0	1.0	2.3	1.0	2.4
				3	3.0	1.9	1.3	1.9	0.7	1.0	2.4	1.0	2.3	1.0	2.1	1.0	2.0
				4	3.5	1.0	2.2	1.5	0.6	1.0	3.2	1.0	2.4	1.0	3.0	1.0	2.1
12 Upstream Half Chamber	18.4	15.9	-2.5	1	6.6	14.3	1.1	10.6	1.9	2.0	3.2	2.0	2.6	3.4	3.1	2.5	0.6
				2	7.1	7.4	1.2	6.9	2.9	1.3	3.7	1.2	3.5	2.7	3.1	2.5	2.7
				4	8.1	3.1	3.6	3.7	4.4	1.4	3.8	1.7	4.2	2.6	4.4	2.0	4.5
	11.0	10.9	-0.1	1	5.0	9.8	1.2	5.2	1.9	1.4	2.6	1.2	2.5	2.5	2.8	1.0	2.9
				2	5.5	4.6	1.1	4.5	2.9	1.2	2.7	1.0	4.5	2.0	3.7	1.0	4.0
				4	6.5	2.0	2.3	2.8	4.1	1.2	5.2	1.0	5.0	2.1	4.1	1.0	5.1
	7.0	6.6	-0.4	1	3.9	7.3	1.1	3.9	1.8	1.4	2.6	1.2	0.6	1.9	2.9	1.0	3.0
				2	4.4	4.0	1.2	3.6	2.9	1.2	2.1	1.0	2.5	2.0	3.9	1.0	4.0
				4	5.4	1.8	1.1	1.8	4.2	1.0	5.1	1.0	4.9	1.8	4.5	1.0	4.7
	3.0	2.0	-1.0	1	2.5	4.0	1.2	3.3	3.0	1.0	0.7	1.0	0.6	1.0	1.0	1.0	0.6
				2	3.0	2.5	1.2	1.9	3.0	1.0	2.8	1.0	2.7	1.0	2.7	1.0	2.6
				4	4.0	1.1	1.2	1.5	3.1	1.0	3.9	1.0	3.8	1.0	2.5	1.0	3.2
	2.0	1.2	-0.8	1	2.0	3.7	1.2	3.0	1.8	1.0	1.8	1.0	1.9	1.0	1.6	1.0	1.2
				2	2.5	2.0	1.1	2.5	2.3	1.0	2.0	1.0	1.9	1.0	2.7	1.0	2.0
				4	3.5	1.9	2.4	2.0	2.8	1.0	3.3	1.0	2.5	1.0	2.8	1.0	2.9
	1.0	0.4	-0.6	1	1.5	2.5	1.5	1.7	1.9	1.0	1.2	1.0	0.6	1.0	0.5	1.0	1.0
				2	2.0	1.7	2.0	1.5	1.7	1.0	2.0	1.0	0.6	1.0	1.8	1.0	1.3
				4	3.0	1.2	1.1	1.0	1.4	1.0	2.3	1.0	2.2	1.0	2.7	1.0	2.9
12 Downstream Half Chamber	18.4	15.9	-2.5	1	6.6	8.3	1.3	12.5	0.5	3.0	2.8	3.2	3.6	4.0	5.5	3.8	6.3
				2	7.1	4.9	2.2	7.0	0.5	2.8	5.1	2.2	7.0	3.2	5.1	3.3	5.0
				3	7.6	3.9	2.4	5.6	0.6	2.7	5.6	1.9	3.3	3.3	4.1	2.5	4.2
				4	8.1	3.0	3.7	4.0	1.9	2.0	6.0	1.8	3.7	2.7	3.2	2.5	6.1

(Continued)

Note: Time listed under hawser forces is time of occurrence after beginning of movement of culvert valve. The 18-barge tow at 12-ft draft has a displacement of 45,360 tons. The 12-barge tow at 12-ft draft has a displacement of 30,240 tons.

Table 6 (Concluded)

No. of Barges	Lift ft	Upper Pool Stage ft	Lower Pool Stage ft	Valve Time min	Filling or Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream: Pull tons	Time min	Longitudinal: Downstream: Pull tons	Time min	Upstream Transverse: Left: Pull tons	Time min	Upstream Transverse: Right: Pull tons	Time min	Downstream Transverse: Left: Pull tons	Time min	Downstream Transverse: Right: Pull tons	Time min
12 Downstream Half Chamber	14.0	12.7	-1.3	1	5.7	6.0	0.9	11.0	0.5	1.6	3.3	1.6	3.0	2.0	3.3	2.5	3.4
				2	6.2	4.0	2.3	6.0	0.5	1.5	2.4	1.8	3.2	2.0	3.9	1.7	3.5
				3	6.7	2.6	2.4	4.0	0.5	1.4	3.4	1.3	3.2	1.9	3.1	1.7	3.5
				4	7.2	1.8	4.8	3.0	0.6	1.7	4.0	1.7	3.3	2.0	5.5	1.7	3.7
	11.0	10.9	-0.1	1	5.0	5.6	3.1	9.1	0.5	1.4	1.6	1.8	4.2	3.0	4.3	1.8	4.4
				2	5.5	4.1	3.2	5.0	0.5	1.6	3.7	1.3	3.8	2.5	3.9	2.2	3.8
				4	6.5	2.2	4.4	2.6	0.6	1.2	3.4	2.5	3.6	1.9	3.9	1.7	3.7
	7.0	6.6	-0.4	1	3.9	4.5	1.1	7.0	0.5	1.0	3.6	1.5	2.4	1.8	3.9	1.2	3.7
				2	4.4	3.2	2.4	4.0	0.6	1.0	3.0	1.2	3.1	1.8	3.0	1.0	3.2
				4	5.4	1.3	3.7	1.5	0.5	1.0	4.0	1.2	3.6	1.8	3.3	1.2	4.3
	3.0	2.0	-1.0	1	2.0	3.7	1.1	3.9	0.5	1.0	1.8	1.0	1.9	1.5	3.0	1.0	1.8
				2	3.5	2.0	2.5	2.0	0.6	1.0	2.2	1.3	3.4	1.8	2.6	1.3	2.3
				4	4.5	1.0	3.4	1.2	2.8	1.0	3.5	1.0	4.1	1.4	3.7	1.2	4.0

Note: Time listed under hawser forces is time of occurrence after beginning of movement of culvert valves. The 12-barge tow at 12-ft draft has a displacement of 30,240 tons.

Table 7

Emptying Characteristics, Type 15 Port Arrangement, Generalized Tests with Barge Tow

No. of Barges	Lift ft	Upper Pool Stage ft	Lower Pool Stage ft	Valve Time min	Filling or Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream Pull tons	Time min	Longitudinal: Downstream Pull tons	Time min	Upstream Transverse: Left Pull tons	Time min	Upstream Transverse: Right Pull tons	Time min	Downstream Transverse: Left Pull tons	Time min	Downstream Transverse: Right Pull tons	Time min
24 Centered	18.4	15.9	-2.5	1	7.2	20.0	1.1	18.8	0.5	2.0	2.0	1.6	3.1	3.6	4.2	4.5	4.7
				2	7.7	12.1	2.2	13.3	1.6	2.6	2.6	1.6	3.2	3.2	5.7	3.7	5.5
				3	8.2	9.0	1.1	9.8	1.7	2.8	4.2	1.8	5.5	2.8	4.1	3.0	3.6
				4	8.7	6.3	1.1	6.3	1.7	1.8	2.7	1.8	4.4	2.5	3.8	2.3	4.0
	14.0	12.7	-1.3	1	6.2	18.0	1.1	17.3	1.6	2.4	2.7	1.8	3.6	2.7	4.3	2.0	4.8
				2	6.7	10.3	1.1	11.9	1.6	2.2	2.6	1.4	2.8	2.8	4.5	2.6	3.6
				3	7.2	8.0	1.1	9.8	1.7	2.0	2.7	1.4	2.9	2.8	4.2	2.5	3.9
				4	7.7	5.4	1.1	6.0	1.7	1.4	3.8	1.3	3.3	2.7	5.0	3.2	5.9
	11.0	10.9	-0.1	1	5.3	17.0	1.1	16.3	1.6	1.9	2.7	1.7	2.1	2.0	4.6	3.1	5.7
				2	5.8	9.0	1.1	9.5	1.7	1.2	2.9	1.4	3.7	1.7	4.7	2.2	4.9
				4	6.8	5.0	1.2	5.0	1.7	1.4	2.4	1.2	3.4	1.7	3.2	1.7	3.4
	7.0	6.6	-0.4	1	4.3	13.3	1.1	12.5	1.7	1.5	3.0	1.0	3.6	2.0	3.4	2.0	3.9
				2	4.8	6.3	2.1	6.8	0.5	1.0	2.0	1.0	2.2	1.6	3.6	1.7	4.1
				4	5.8	4.6	2.3	4.9	0.6	1.0	4.8	1.0	5.4	1.5	2.8	1.8	3.7
	5.0	4.8	-0.2	1	3.7	10.8	1.1	9.7	0.5	1.0	1.9	1.0	2.9	2.0	2.3	1.5	2.1
				2	4.2	5.2	1.1	6.0	0.5	1.0	3.6	1.0	3.3	2.0	2.7	1.0	3.7
				4	5.2	3.3	1.2	4.0	0.6	1.0	2.0	1.0	2.2	1.4	4.8	1.2	3.0
	3.0	2.0	-1.0	1	2.8	7.0	1.1	7.0	0.5	1.0	1.9	1.0	2.1	1.3	2.3	1.0	2.5
				2	3.3	3.9	1.2	4.9	0.5	1.0	0.4	1.0	0.9	1.3	2.8	1.3	3.8
				4	4.3	2.5	1.2	3.5	0.6	1.0	3.5	1.0	3.4	1.0	3.4	1.0	4.5
	2.0	1.2	-0.8	1	2.2	5.4	1.1	6.1	0.5	1.0	2.1	1.0	2.0	1.0	1.4	1.0	2.2
				2	2.7	3.3	2.3	4.7	0.5	1.0	1.6	1.0	1.5	1.0	2.5	1.0	2.4
				4	3.7	1.7	1.2	2.9	0.6	1.0	2.7	1.0	2.9	1.0	2.7	1.0	2.9
	1.0	0.4	-0.6	1	1.6	2.9	1.1	4.1	0.5	1.0	1.5	1.0	1.3	1.0	0.8	1.0	0.9
				2	2.1	2.9	2.0	3.2	0.5	1.0	1.2	1.0	1.8	1.0	1.9	1.0	1.8
				4	3.1	1.9	2.6	2.3	0.5	1.0	2.5	1.0	2.6	1.0	2.7	1.0	2.1

(Continued)

Note: Time listed under hawser forces is time of occurrence after beginning of movement of culvert valve. The 24-barge tow at 12-ft draft has a displacement of 60,480 tons.

(Sheet 1 of 4)

Table 7 (Continued)

No. of Barges	Lift ft	Upper Pool Stage ft	Lower Pool Stage ft	Valve Time min	Filling or Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream: Pull tons	Time min	Longitudinal: Downstream: Pull tons	Time min	Upstream Transverse: Left: Pull tons	Time min	Upstream Transverse: Right: Pull tons	Time min	Downstream Transverse: Left: Pull tons	Time min	Downstream Transverse: Right: Pull tons	Time min
18 Centered	18.4	15.9	-2.5	1	7.2	12.2	1.0	12.3	0.5	1.0	5.4	1.0	2.1	1.5	1.9	1.6	2.5
				2	7.7	7.8	2.1	9.4	1.5	1.0	5.9	1.0	6.9	2.0	6.3	1.5	5.7
				3	8.2	5.8	1.1	7.0	0.6	1.0	5.1	1.0	5.2	1.4	4.6	1.5	5.3
				4	8.7	3.8	1.1	4.3	0.5	1.0	3.9	1.0	2.7	1.6	5.8	1.6	7.2
	14.0	12.7	-1.3	1	6.2	10.8	1.0	9.8	0.5	1.2	4.8	1.0	5.9	1.8	5.0	2.0	5.1
				2	6.7	6.6	1.1	8.2	1.6	1.2	5.1	1.0	5.7	1.4	6.3	1.3	2.3
				3	7.2	4.7	1.1	6.0	1.6	1.2	5.2	1.0	5.3	1.7	2.0	1.6	6.8
				4	7.7	3.2	1.1	4.0	1.6	1.2	2.7	1.0	2.9	1.7	3.3	1.8	6.9
	11.0	10.9	-0.1	1	5.3	11.2	1.0	9.5	0.5	2.0	4.1	1.4	4.2	2.7	4.4	2.2	5.0
				2	5.8	6.9	2.2	5.9	1.6	1.0	2.2	1.0	5.4	1.5	4.5	1.3	2.6
				3	6.3	4.3	1.1	5.0	0.5	1.0	4.3	1.0	4.4	1.2	4.0	1.0	4.1
				4	6.8	3.1	1.1	3.8	0.5	1.0	3.5	1.0	3.2	1.9	2.7	1.8	2.9
	7.0	6.6	-0.4	1	4.3	8.8	1.1	7.5	0.5	1.0	4.1	1.2	3.5	1.0	4.0	1.6	3.2
				2	4.8	4.1	1.1	5.0	0.5	1.6	2.9	1.0	2.8	2.0	2.6	2.0	3.3
				3	5.3	3.3	1.1	4.0	0.5	1.0	4.0	1.0	3.9	1.7	3.6	1.5	2.5
				4	5.8	3.0	1.2	3.5	0.5	1.0	5.2	1.0	5.2	1.0	1.9	1.3	5.0
	5.0	4.8	-0.2	1	3.7	7.7	1.1	6.7	0.5	1.6	4.1	1.6	3.2	1.8	2.9	2.0	2.8
				2	4.2	3.9	1.1	4.1	0.5	1.0	3.2	1.0	3.3	1.5	2.3	1.2	2.2
				3	4.7	3.3	2.3	2.4	0.5	1.0	3.1	1.0	3.2	1.5	4.0	1.0	2.4
				4	5.2	2.7	1.2	2.4	0.5	1.2	3.5	1.0	2.7	1.4	4.2	1.2	4.1
	3.0	2.0	-1.0	1	2.8	5.8	1.1	4.8	0.4	1.0	3.2	1.0	2.0	1.0	2.3	1.5	2.0
				2	3.3	2.8	1.1	3.0	0.5	1.0	2.9	1.0	3.0	1.0	3.0	1.0	3.0
				3	3.8	2.1	2.1	3.0	0.5	1.0	3.7	1.0	3.4	1.0	3.0	1.2	3.0
				4	4.3	2.0	2.0	2.4	0.5	1.0	3.1	1.0	4.0	1.0	4.0	1.0	3.5
	2.0	1.2	-0.8	1	2.2	3.4	1.1	4.4	0.5	1.0	2.3	1.0	2.0	1.0	1.8	1.2	1.3
				2	2.7	2.0	1.1	3.2	0.5	1.0	1.7	1.0	1.9	1.0	1.9	1.0	2.0
				3	3.2	1.9	2.3	2.4	0.5	1.0	3.1	1.0	3.0	1.0	2.8	1.0	2.7
				4	3.7	1.6	3.6	1.8	1.7	1.0	2.4	1.0	3.0	1.0	2.7	1.0	3.5

(Continued)

Note: Time listed under hawser stresses is time of occurrence after beginning of movement of culvert valve. The 18-barge tow at 12-ft draft has a displacement of 45,360 tons.

Table 7 (Continued)

					Filling or	Maximum Hawser Forces															
						Longitudinal				Upstream Transverse				Downstream Transverse			
		Upper	Lower	Valve	Emptying	Upstream		Downstream		Left		Right		Left		Right	
No. of Barges	Lift ft	Pool Stage ft	Pool Stage ft	Time min	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
12 Upstream Half Chamber	18.4	15.9	-2.5	1	7.2	5.4	3.2	11.8	0.5	1.2	5.0	1.7	3.2	1.2	2.7	1.7	2.6
				2	7.7	4.6	3.3	7.3	1.6	1.0	2.0	1.0	2.8	1.2	1.7	1.2	2.6
				4	8.7	2.4	6.5	3.9	0.5	1.0	7.4	1.0	7.5	1.0	4.5	1.2	3.5
	11.0	10.9	-0.1	1	5.3	4.6	2.2	9.5	0.5	1.2	4.1	1.0	3.2	1.7	4.7	2.1	3.6
				2	5.8	4.0	3.3	5.6	0.5	1.3	3.7	1.3	3.6	2.2	4.1	2.0	4.8
				4	6.8	2.0	2.3	2.8	4.1	1.2	5.2	1.0	5.0	2.1	4.1	1.0	5.1
	7.0	6.6	-0.4	1	4.3	5.0	2.1	7.3	0.4	1.0	2.9	1.0	3.0	1.0	2.1	1.1	3.7
				2	4.8	3.2	3.4	5.0	0.5	1.2	4.4	1.1	3.5	1.7	4.6	2.0	4.5
				4	5.8	1.9	5.5	2.9	0.5	1.0	4.3	1.0	4.2	1.5	3.1	1.2	3.2
	3.0	2.0	-1.0	1	2.8	3.7	1.2	5.0	0.4	1.0	1.4	1.0	1.5	1.0	2.4	1.0	2.5
				2	3.3	2.2	3.3	3.0	0.5	1.0	3.5	1.0	3.0	1.2	3.0	1.0	3.0
				4	4.3	2.2	0.5	1.7	4.0	1.0	3.6	1.0	3.5	1.0	2.1	1.0	2.0
	2.0	1.2	-0.8	1	2.2	3.0	2.2	3.6	0.4	1.0	2.0	1.0	2.0	1.0	1.9	1.0	1.8
				2	2.7	2.0	2.4	3.1	0.5	1.0	2.1	1.0	2.6	1.0	2.5	1.0	2.6
				4	3.7	1.8	3.3	2.9	1.3	1.0	3.3	1.0	3.2	1.0	3.2	1.0	3.1
	1.0	0.4	-0.6	1	1.6	2.8	1.2	3.0	0.5	1.0	1.7	1.0	0.6	1.0	0.9	1.0	1.2
				2	2.1	1.7	2.0	2.0	0.6	1.0	1.8	1.0	0.6	1.0	2.0	1.0	1.3
				4	3.1	1.1	2.6	1.4	0.6	1.0	3.0	1.0	3.0	1.0	2.0	1.0	2.5
12 Downstream Half Chamber	18.4	15.9	-2.5	1	7.2	12.9	0.9	5.3	0.5	1.4	4.8	1.3	4.9	2.0	4.8	2.0	4.7
				2	7.7	6.3	1.0	3.6	0.5	1.4	5.9	1.4	6.0	2.0	5.8	2.0	5.9
				3	8.2	5.0	1.0	3.0	0.5	1.4	2.7	1.9	5.0	2.0	5.1	2.0	4.8
				4	8.7	3.9	1.0	2.2	0.6	1.5	7.2	1.5	7.1	2.0	5.7	1.8	7.6
	14.0	12.7	-1.3	1	6.2	11.0	1.0	4.9	5.0	1.0	3.4	1.0	2.5	1.0	1.4	1.0	1.5
				2	6.7	6.5	1.0	3.0	1.6	1.0	0.9	1.2	4.1	1.2	3.0	1.0	1.4
				3	7.2	4.9	1.0	2.6	0.6	1.0	5.0	1.0	4.6	1.2	4.9	1.0	4.9
				4	7.7	3.5	1.0	1.7	0.6	1.0	6.4	1.0	6.5	1.2	5.3	1.2	4.8

(Continued)

Note: Time listed under hawser stresses is time of occurrence after beginning of movement of culvert valves. The 12-barge tow at 12-ft draft has a displacement of 30,240 tons.

Table 7 (Concluded)

No. of Barges	Lift ft	Upper Pool Stage ft	Lower Pool Stage ft	Valve Time min	Filling or Emptying Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Time min	Longitudinal, Downstream, Pull tons	Time min	Upstream Transverse, Left, Pull tons	Time min	Upstream Transverse, Right, Pull tons	Time min	Downstream Transverse, Left, Pull tons	Time min	Downstream Transverse, Right, Pull tons	Time min
12 Downstream Half Chamber	11.0	10.9	-0.1	1	5.3	9.6	1.8	4.5	1.5	1.0	1.2	1.4	1.3	1.6	1.0	1.2	1.1
				2	5.8	5.9	1.0	2.6	1.3	1.0	2.5	1.0	2.6	1.3	2.0	1.0	5.7
				4	6.8	3.2	1.1	1.9	1.6	1.0	1.8	1.0	1.9	1.5	3.1	1.3	2.8
	7.0	6.6	-0.4	1	4.3	8.1	1.0	3.2	0.6	1.0	1.5	1.2	3.3	1.2	3.3	1.1	1.3
				2	4.8	4.7	1.0	2.3	0.6	1.0	4.8	1.2	4.7	1.5	4.5	1.2	4.6
				4	5.8	3.0	1.1	1.4	0.6	1.0	5.6	1.0	5.6	1.0	3.1	1.0	2.6
	3.0	2.0	-1.0	1	2.8	4.3	1.0	2.0	0.5	1.0	2.5	1.2	2.6	1.6	2.7	1.7	2.6
				2	3.3	3.0	1.0	1.7	0.6	1.0	2.9	1.2	3.3	1.8	3.1	1.5	3.0
				4	4.3	2.3	2.3	1.2	0.6	1.3	2.9	1.0	2.8	1.5	3.0	2.1	3.1

Note: Time listed under hawser stresses is time of occurrence after beginning of movement of culvert valves. The 12-barge tow at 12-ft draft has a displacement of 30,240 tons.

Table 8

Filling and Emptying Characteristics, Type 15 Port Arrangement, Reverse Head Tests with Barge Tow

No. of Barges	Head ft	Gulf Side Upper Pool Stage ft	River Side Lower Pool Stage ft	Valve Time min	Filling or Emptying Time min	Maximum Hawser Forces											
						Longitudinal				Upstream Transverse				Downstream Transverse			
						Upstream		Downstream		Left		Right		Left		Right	
						Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
						Filling (Reverse Head)											
18 Centered	2.1	5.1	3.0	1	2.1	4.8	1.0	3.7	0.5	1.0	1.4	1.0	1.2	1.0	1.3	1.2	1.4
				2	2.6	4.2	1.1	3.2	0.5	1.0	1.9	1.0	1.8	1.0	1.9	1.7	2.0
				4	3.6	2.0	1.1	2.0	0.6	1.0	2.3	1.0	2.2	1.0	2.0	1.0	2.1
	1.0	0.5	-0.5	1	1.5	2.4	1.0	2.4	0.5	1.0	1.2	1.0	1.3	1.0	1.0	1.0	1.1
				2	2.0	2.0	1.5	2.2	0.6	1.0	1.2	1.0	1.3	1.0	1.4	1.0	1.5
				4	3.0	1.5	2.3	1.3	0.4	1.0	2.1	1.0	2.0	1.0	2.3	1.0	2.4
						Emptying (Reverse Head)											
18 Centered	2.1	5.1	3.0	1	2.3	3.2	1.2	3.5	0.6	1.0	1.3	1.0	2.0	1.0	2.0	1.0	1.9
				2	2.7	2.2	2.3	2.6	0.5	1.0	1.3	1.0	2.5	1.0	2.3	1.0	2.2
				4	3.5	2.0	2.3	1.7	0.6	1.0	3.2	1.0	3.1	1.0	2.2	1.0	2.4
	1.0	0.5	-0.5	1	1.6	2.1	1.1	2.2	0.6	1.0	1.3	1.0	1.2	1.0	1.4	1.0	1.3
				2	2.0	1.5	1.2	1.6	0.6	1.0	1.9	1.0	2.3	1.0	1.9	1.0	1.8
				4	2.8	1.2	1.3	1.0	0.6	1.0	2.6	1.0	2.7	1.0	1.9	1.0	1.8

Note: Time listed under hawser forces is time of occurrence after beginning of movement of culvert valve. The 18-barge tow at 12-ft draft has a displacement of 45,360 tons.

Table 9

Filling Characteristics, Type 15 Port Arrangement, 900- by 140-ft Ship at 45-ft Draft (2+00)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal: Upstream Pull tons	Upstream Time min	Downstream Pull tons	Downstream Time min	Upstream Transverse: Left Pull tons	Left Time min	Right Pull tons	Right Time min	Downstream Transverse: Left Pull tons	Left Time min	Right Pull tons	Right Time min
18.4	3.28	Original	4	8.1	46.0	2.7	54.0	0.9	12.0	2.5	5.0	0.3	12.2	2.8	12.0	0.6
			6	9.1	31.8	2.7	40.8	1.0	10.3	3.1	6.0	0.3	12.3	4.3	12.2	0.7
			8	10.1	26.0	2.8	31.5	1.0	7.8	1.5	6.2	0.3	7.0	1.8	12.0	0.7
	7.88	+4.6	4	8.1	37.8	2.1	44.0	0.7	4.6	2.3	2.0	0.2	5.0	4.1	4.1	0.5
			6	9.1	28.0	2.2	28.6	1.1	4.4	3.7	1.9	2.0	4.5	6.2	4.0	6.7
			8	10.1	24.0	--	24.0	--	4.2	--	2.0	4.0	--	3.0	--	--
	11.4	+8.12	4	8.1	32.0	1.6	35.5	0.7	5.6	2.9	2.2	5.3	4.0	4.8	4.5	5.1
			6	9.1	25.5	2.0	22.9	1.1	5.3	5.0	2.2	5.7	5.6	5.2	3.6	5.5
			8	10.1	21.6	2.0	18.2	1.0	3.8	4.2	1.6	4.0	4.4	5.0	2.7	6.0
	16.0	+12.72	4	8.1	30.5	1.6	29.0	0.6	5.5	3.5	1.0	0.8	2.0	1.4	6.0	3.0
			6	9.1	21.0	1.8	19.5	0.6	4.0	6.5	1.5	5.9	1.5	6.4	5.7	5.7
			8	10.1	17.0	1.9	14.7	0.6	2.8	5.4	1.0	4.1	1.0	7.8	4.0	5.9
	19.0	+15.72	4	8.1	27.5	1.5	26.4	0.6	6.0	3.4	1.5	6.9	4.0	6.4	5.3	4.1
			6	9.1	18.0	1.5	17.2	0.6	3.1	5.3	1.0	0.8	1.2	3.0	3.7	3.7
			8	10.1	13.0	1.5	13.5	0.5	3.3	6.7	1.3	8.4	1.5	8.9	3.3	8.2
	22.0	+18.72	4	8.1	25.7	1.5	24.0	0.6	4.4	4.1	1.2	6.8	1.9	1.3	3.5	3.5
			6	9.1	16.5	1.4	15.3	0.5	3.8	4.3	1.0	0.9	1.0	1.3	3.8	5.1
			8	10.1	12.0	1.7	12.2	0.6	3.0	6.6	1.0	2.1	1.6	1.2	2.0	8.0
	26.0	+22.72	4	8.1	22.1	1.4	20.0	0.6	4.3	3.5	1.1	1.9	2.5	1.3	4.9	4.0
			6	9.1	15.2	1.5	13.5	0.5	3.5	5.5	1.0	1.8	1.2	1.4	2.8	4.6
			8	10.1	10.8	1.4	10.9	0.5	3.2	5.7	1.0	2.0	2.5	8.3	3.3	6.2
14.0	4.48	Original	4	7.2	41.0	2.5	45.0	0.8	6.9	1.8	3.6	0.2	8.8	3.9	7.8	0.6
			6	8.2	29.0	2.5	31.9	1.0	6.7	3.9	3.8	0.3	7.2	5.0	7.2	0.6
			8	9.2	22.2	2.6	26.0	1.1	6.4	1.3	4.1	0.3	6.5	5.1	7.8	0.6

(Continued)

Table 9 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Longitudinal, Upstream, Time min	Longitudinal, Downstream, Pull tons	Longitudinal, Downstream, Time min	Upstream Transverse, Left, Pull tons	Upstream Transverse, Left, Time min	Upstream Transverse, Right, Pull tons	Upstream Transverse, Right, Time min	Downstream Transverse, Left, Pull tons	Downstream Transverse, Left, Time min	Downstream Transverse, Right, Pull tons	Downstream Transverse, Right, Time min
14.0	15.00	+10.52	4	7.2	28.0	1.8	25.0	0.7	3.5	5.2	1.4	5.5	1.7	5.1	3.3	3.4
			6	8.2	21.5	1.9	16.0	0.9	2.5	4.3	1.3	2.4	1.1	1.9	3.0	3.8
			8	9.2	15.7	2.0	12.8	0.6	2.4	6.3	1.0	2.4	1.8	8.5	2.6	4.8
	19.00	+14.52	4	7.2	26.5	1.6	21.0	0.7	3.5	3.1	1.2	6.9	2.5	6.4	2.8	2.4
			6	8.2	17.0	1.8	14.6	0.6	2.5	4.1	1.0	2.3	1.0	1.8	2.0	3.7
			8	9.2	12.2	1.8	12.0	0.5	2.5	4.6	1.0	4.4	2.5	7.8	1.3	7.0
	25.00	+20.52	4	7.2	24.8	1.5	20.8	0.6	3.7	3.9	1.0	6.2	1.0	4.2	3.2	4.4
			6	8.2	15.0	1.4	12.0	0.5	3.1	5.4	1.0	0.8	1.0	7.3	2.9	4.9
			8	9.2	9.0	1.5	10.0	0.6	2.0	5.8	1.0	8.1	1.3	8.4	1.7	7.2
11.0	5.68	Original	4	6.5	35.0	2.5	38.0	0.9	4.8	1.2	2.6	0.2	5.7	3.6	5.2	0.6
			6	7.5	25.0	2.5	26.8	0.9	5.2	2.6	2.5	0.3	5.2	4.5	5.3	0.6
			8	8.5	20.3	2.5	22.0	1.0	4.6	1.3	3.0	0.3	4.9	4.2	5.3	0.6
	9.40	+3.72	4	6.5	27.2	2.1	29.4	0.7	2.4	3.8	2.4	4.5	1.9	5.1	4.8	3.2
			6	7.5	20.7	2.1	20.7	1.0	1.7	5.9	1.1	1.0	1.8	1.7	3.0	0.7
			8	8.5	15.4	2.1	16.8	1.0	2.0	4.8	1.0	4.1	1.0	5.8	3.7	5.4
	14.52	+8.84	4	6.5	21.7	1.6	22.3	0.6	2.9	3.6	2.0	4.4	2.9	1.5	3.9	4.6
			6	7.5	17.0	2.0	16.0	0.9	2.3	5.4	1.5	6.9	1.9	3.0	2.1	3.9
			8	8.5	13.3	2.0	13.9	1.0	1.9	4.8	1.0	7.5	1.1	3.4	1.5	6.6
	17.52	+11.84	4	6.5	22.5	1.6	20.7	0.7	2.8	3.8	1.5	5.5	2.0	1.5	2.7	3.3
			6	7.5	15.5	1.9	14.5	0.9	2.7	4.7	1.2	1.8	1.6	1.4	3.2	4.2
			8	8.5	11.3	1.9	12.0	0.5	1.8	4.9	1.2	7.4	1.2	6.8	1.7	6.5
	20.52	+14.84	4	6.5	20.7	1.5	19.0	0.6	3.4	3.8	1.2	5.5	1.7	3.6	4.6	4.3
			6	7.5	13.2	1.8	11.8	0.6	2.2	4.6	1.0	2.4	1.0	1.5	3.0	5.2
			8	8.5	8.6	1.7	10.1	0.5	1.9	5.8	1.0	8.1	1.2	3.3	1.6	6.3
	24.52	+18.84	4	6.5	20.0	1.5	17.8	0.7	2.7	3.5	1.0	2.0	1.7	1.3	2.2	3.4
			6	7.5	11.2	1.5	12.1	0.6	1.9	4.6	1.0	0.3	1.0	4.5	1.9	6.4
			8	8.5	6.3	1.4	7.9	0.5	1.8	5.5	1.0	0.8	1.1	1.2	2.0	6.3

(Continued)

Table 9 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Longitudinal, Upstream, Time min	Longitudinal, Downstream, Pull tons	Longitudinal, Downstream, Time min	Upstream Transverse, Left, Pull tons	Upstream Transverse, Left, Time min	Upstream Transverse, Right, Pull tons	Upstream Transverse, Right, Time min	Downstream Transverse, Left, Pull tons	Downstream Transverse, Left, Time min	Downstream Transverse, Right, Pull tons	Downstream Transverse, Right, Time min
7.0	5.38	Original	4	5.4	29.5	2.4	30.8	0.8	4.8	3.6	2.0	0.2	5.2	4.0	4.8	0.6
			6	6.4	22.2	2.5	23.2	0.9	2.7	1.3	2.7	0.8	4.0	5.2	4.5	0.8
			8	7.4	18.2	2.5	19.0	1.8	3.7	1.2	2.3	0.3	3.3	4.1	4.3	0.6
	7.88	+2.5	4	5.4	25.2	2.3	25.2	0.8	1.2	3.1	1.0	3.5	1.0	1.6	3.0	3.7
			6	6.4	19.0	2.2	20.0	1.1	1.3	5.6	1.4	5.2	1.2	5.1	2.2	5.0
			8	7.4	16.1	2.2	16.3	1.2	1.0	6.1	1.0	6.7	1.0	6.3	2.0	5.4
	11.20	+5.82	4	5.4	21.9	2.1	20.0	1.0	2.0	4.2	1.6	4.9	1.0	4.4	3.0	4.7
			6	6.4	17.5	2.1	16.0	1.1	1.2	4.4	1.0	2.7	1.0	1.9	1.5	3.9
			8	7.4	13.6	2.1	13.8	1.1	1.3	5.4	1.0	6.1	1.2	5.6	1.3	4.9
	15.80	+10.42	4	5.4	18.0	1.9	17.3	0.6	1.2	1.4	1.0	2.4	1.2	1.6	2.0	0.4
			6	6.4	4.5	2.0	13.3	1.0	1.0	3.2	1.0	2.0	1.0	1.7	1.0	2.7
			8	7.4	11.7	2.0	10.3	1.1	1.0	3.8	1.0	0.2	1.0	1.6	1.0	0.8
	18.80	+13.42	4	5.4	16.6	1.6	17.0	0.6	1.0	3.0	1.0	2.3	1.0	1.5	1.5	4.7
			6	6.4	12.2	1.9	12.3	0.6	1.2	4.8	1.0	5.5	1.0	5.0	1.5	4.2
			8	7.4	9.0	2.0	9.3	0.6	1.0	4.7	1.0	1.9	1.0	3.4	1.0	3.1
	21.80	+16.42	4	5.4	14.8	1.5	14.4	0.6	1.0	1.2	1.0	2.0	1.0	1.5	1.6	2.3
			6	6.4	9.6	1.4	10.7	0.5	1.1	5.1	1.0	2.3	1.0	4.8	1.1	4.6
			8	7.4	6.0	1.8	7.4	0.5	1.2	6.3	1.0	6.9	1.0	6.5	1.5	6.3
	25.8	+20.82	4	5.4	14.0	1.5	13.8	0.6	2.0	4.3	1.0	4.9	1.1	4.4	1.5	3.9
			6	6.4	8.5	1.5	8.8	0.6	1.6	3.9	1.0	4.2	1.0	4.1	1.0	3.9
			8	7.4	5.2	1.4	6.2	0.5	1.0	6.4	1.0	2.7	1.0	6.1	1.2	6.1
5.0	5.58	Original	3	4.2	40.0	2.4	35.0	0.8	3.4	1.9	2.0	0.1	3.7	2.3	3.9	0.5
			4	4.7	28.0	2.4	26.0	1.3	3.0	2.5	1.7	0.2	3.3	2.2	3.5	0.6
			6	5.7	18.2	2.3	20.0	1.3	2.7	1.2	2.0	0.3	2.6	1.0	8.4	0.6
	11.40	+5.82	3	4.2	29.5	2.0	25.9	0.7	1.9	2.9	1.5	3.3	2.0	1.6	3.0	3.5
			4	4.7	19.5	2.1	18.7	0.7	1.3	3.9	1.0	0.7	1.0	1.7	1.6	0.9
			6	5.7	14.2	2.2	11.1	1.1	1.2	3.1	1.0	0.2	1.0	1.8	1.9	4.9

(Continued)

Table 9 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Longitudinal Upstream Pull tons	Longitudinal Upstream Time min	Longitudinal Downstream Pull tons	Longitudinal Downstream Time min	Upstream Transverse Left Pull tons	Upstream Transverse Left Time min	Upstream Transverse Right Pull tons	Upstream Transverse Right Time min	Downstream Transverse Left Pull tons	Downstream Transverse Left Time min	Downstream Transverse Right Pull tons	Downstream Transverse Right Time min
5.0	16.00	+10.42	3	4.2	23.8	1.7	23.0	0.6	1.7	3.8	1.2	2.0	2.5	1.5	2.5	3.3
			4	4.7	15.6	1.9	16.0	0.6	1.2	2.9	1.0	1.1	1.0	1.6	1.5	0.8
			6	5.7	9.8	2.0	9.8	0.7	1.1	4.8	1.0	2.4	1.0	4.0	1.0	2.6
	22.00	+16.42	3	4.2	21.0	1.5	20.0	0.7	2.2	1.3	1.3	0.8	2.2	1.4	2.4	0.6
			4	4.7	11.8	1.5	13.0	0.6	1.1	1.2	1.0	0.9	1.0	0.4	1.3	0.6
			6	5.7	7.9	1.8	9.1	0.6	1.0	4.4	1.0	2.2	1.0	3.2	1.0	2.0
	26.00	+20.42	3	4.2	19.0	1.5	19.0	0.6	1.4	2.4	1.0	0.7	1.1	1.5	1.7	3.1
			4	4.7	12.1	1.5	12.1	0.6	1.3	3.1	1.0	0.3	1.0	2.9	1.5	3.7
			6	5.7	7.1	1.4	8.0	0.5	1.0	2.5	1.0	0.2	1.0	2.3	1.0	0.3
3.0	4.78	Original	2	3.0	46.0	2.1	37.0	0.8	3.0	1.7	1.5	0.2	3.0	2.2	3.2	0.6
			4	4.0	23.0	2.3	23.0	1.2	2.5	1.2	1.6	0.2	2.3	2.3	3.3	0.6
			6	5.0	15.5	2.4	17.2	1.2	2.1	1.2	1.7	0.3	1.5	1.0	3.2	0.6
	7.88	+3.1	2	3.0	40.0	2.3	27.5	1.0	1.4	2.0	1.2	0.3	1.6	1.5	2.2	0.7
			4	4.0	20.8	2.3	18.0	1.2	1.0	2.3	1.4	2.8	1.4	2.1	1.4	0.5
			6	5.0	13.8	1.2	14.5	1.2	1.0	2.3	1.0	3.2	1.0	2.4	1.0	2.9
	11.20	+6.42	2	3.0	31.8	2.1	24.0	0.8	1.9	1.8	1.2	0.2	1.5	1.7	2.2	2.4
			4	4.0	17.0	2.2	14.0	1.1	1.0	4.2	1.0	2.8	1.0	2.1	1.2	1.0
			6	5.0	11.6	2.2	10.9	1.1	1.0	1.5	1.0	1.2	1.0	1.8	1.2	0.9
	15.80	+11.02	2	3.0	23.0	1.8	22.0	0.7	1.0	1.7	1.0	2.1	1.3	1.6	1.3	0.6
			4	4.0	13.0	2.1	13.0	0.7	1.0	1.4	1.0	0.5	1.0	2.2	1.0	0.8
			6	5.0	8.0	2.0	9.0	1.0	1.0	1.5	1.0	0.2	1.0	1.8	1.0	1.0
	18.80	+14.02	2	3.0	18.0	1.6	17.7	0.6	2.2	0.4	1.7	0.7	2.0	1.3	2.7	2.2
			4	4.0	10.0	1.7	11.0	0.8	1.3	3.7	1.0	2.2	1.0	1.4	1.0	1.0
			6	5.0	5.8	1.9	6.7	0.6	1.0	0.9	1.0	0.2	1.0	2.8	1.0	0.4
	25.80	+21.02	2	3.0	16.0	1.5	13.7	0.7	1.8	1.3	1.0	2.0	1.8	1.4	2.3	0.7
			4	4.0	9.1	1.5	7.8	0.6	1.0	1.3	1.0	2.2	1.0	1.5	1.0	0.7
			6	5.0	4.0	1.4	4.2	0.5	1.0	0.7	1.0	4.0	1.0	2.6	1.0	0.3

(Continued)

Table 9 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal Upstream Pull tons	Longitudinal Upstream Time min	Longitudinal Downstream Pull tons	Longitudinal Downstream Time min	Upstream Transverse Left Pull tons	Upstream Transverse Left Time min	Upstream Transverse Right Pull tons	Upstream Transverse Right Time min	Downstream Transverse Left Pull tons	Downstream Transverse Left Time min	Downstream Transverse Right Pull tons	Downstream Transverse Right Time min
2.0	4.98	Original	1	2.0	48.0	1.8	39.0	0.8	2.6	1.2	1.0	0.1	2.2	1.0	2.0	0.9
			2	2.5	36.0	2.3	28.7	0.7	2.3	1.0	1.2	0.1	1.8	1.3	2.7	0.6
			4	3.5	18.2	2.3	19.5	1.2	1.6	2.3	1.2	0.3	2.0	2.3	2.5	0.6
	10.40	+5.42	1	2.0	36.0	2.1	26.8	0.8	1.7	1.8	1.2	1.6	2.0	1.7	1.9	1.3
			2	2.5	24.0	2.1	19.0	0.8	1.7	1.5	1.1	2.4	1.9	1.7	2.0	1.0
			4	3.5	11.2	2.2	11.0	0.7	1.0	2.1	1.0	2.5	1.0	1.8	1.1	2.8
	15.00	+10.02	1	2.0	31.0	1.7	22.0	0.7	1.2	1.3	2.0	1.0	1.8	1.5	3.0	0.7
			2	2.5	18.0	1.8	16.0	0.8	1.0	1.5	1.6	2.1	1.0	1.5	2.0	0.9
			4	3.5	10.0	2.0	9.5	1.1	1.0	0.8	1.3	0.3	1.0	1.8	2.0	0.5
	19.00	+14.02	1	2.0	28.5	1.6	22.0	0.7	1.1	1.4	1.3	2.0	1.2	1.4	1.8	0.9
			2	2.5	15.0	1.7	14.4	0.7	1.0	1.6	1.5	2.0	1.7	1.6	1.3	2.2
			4	3.5	6.5	1.8	8.8	0.8	1.0	2.1	1.0	1.3	1.0	2.3	1.2	0.5
	25.00	+20.02	1	2.0	--	--	--	--	--	--	--	--	--	--	--	--
			2	2.5	--	--	--	--	--	--	--	--	--	--	--	--
			4	3.6	--	--	--	--	--	--	--	--	--	--	--	--
1.0	5.18	Same	1	1.5	31.5	1.3	22.5	0.5	1.5	0.9	1.0	0.1	1.3	1.0	1.8	0.9
			2	2.0	24.5	1.7	19.0	0.8	1.1	1.2	1.0	0.1	1.7	1.7	1.8	0.6
			4	3.0	13.6	2.3	15.0	1.1	1.7	2.1	1.0	0.2	1.5	1.8	1.7	0.6
	10.40	+5.22	1	1.5	23.8	2.2	16.0	0.8	1.1	1.8	1.0	1.0	1.6	1.0	1.2	0.9
			2	2.0	17.1	2.2	13.5	0.9	1.9	0.2	1.2	2.3	1.9	1.7	2.7	0.8
			4	3.0	9.2	2.2	8.9	0.8	1.1	1.8	1.0	3.1	1.1	1.8	1.1	1.0
	15.00	+9.82	1	1.5	17.6	1.9	13.5	0.7	1.3	1.2	1.0	0.9	1.2	1.4	2.0	0.7
			2	2.0	12.3	2.0	10.6	0.7	1.0	1.4	1.0	0.7	1.1	1.6	1.7	0.8
			4	3.0	5.8	2.0	7.2	0.7	1.0	3.0	1.0	1.2	1.0	1.8	1.0	0.9
	19.00	+13.82	1	1.5	16.0	1.7	11.4	0.7	1.0	1.5	1.0	1.0	1.0	1.4	1.3	0.8
			2	2.0	11.2	1.8	10.0	0.7	1.2	0.6	1.0	1.0	1.0	1.9	1.3	1.1
			4	3.0	5.7	1.8	7.1	0.9	1.0	1.1	1.0	1.4	1.0	2.0	1.3	0.6

(Continued)

Table 9 (Concluded)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces															
					Longitudinal				Upstream Transverse				Downstream Transverse			
					Upstream		Downstream		Left		Right		Left		Right	
					Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
1.0	25.00	+19.82	1	1.5	11.3	1.5	9.8	0.7	1.0	1.5	1.0	0.8	1.0	1.3	1.5	0.6
			2	2.0	7.4	1.6	8.0	0.7	1.0	1.1	1.0	0.4	1.0	2.4	1.2	0.6
			4	3.0	4.6	1.5	6.3	0.6	1.0	1.4	1.0	1.1	1.0	1.6	1.0	0.9

Table 10

Filling Characteristics, Type 15 Port Arrangement, 900- by 140-ft Ship at 37.5-ft Draft (2+00)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Longitudinal, Upstream, Time min	Longitudinal, Downstream, Pull tons	Longitudinal, Downstream, Time min	Upstream Transverse, Left, Pull tons	Upstream Transverse, Left, Time min	Upstream Transverse, Right, Pull tons	Upstream Transverse, Right, Time min	Downstream Transverse, Left, Pull tons	Downstream Transverse, Left, Time min	Downstream Transverse, Right, Pull tons	Downstream Transverse, Right, Time min
18.4	10.78	Original	2	7.1	48.0	1.6	48.0	0.7	3.9	3.7	2.0	5.5	2.9	3.9	6.5	1.7
			4	8.1	28.4	2.1	31.5	0.8	3.5	3.3	3.0	0.2	5.0	3.1	3.6	2.4
			6	9.1	23.6	2.1	24.4	1.0	2.1	5.2	3.0	0.2	5.0	5.0	3.5	0.4
			8	10.1	20.2	2.2	20.0	1.2	3.5	6.0	2.3	0.3	4.0	6.2	3.6	0.5
	15.38	+4.60	2	7.1	44.0	1.5	44.0	0.6	4.8	2.1	1.5	5.4	3.3	3.2	5.3	2.6
			4	8.1	24.0	1.6	23.0	0.6	3.2	3.8	1.3	1.8	1.3	1.3	3.5	4.2
			6	9.1	18.0	1.7	15.0	0.6	3.2	5.9	1.1	7.1	2.3	5.8	3.0	5.5
			8	10.1	13.8	1.8	12.3	0.9	3.9	6.1	1.9	8.0	3.3	7.5	2.6	6.0
	18.90	+8.10	2	7.1	41.0	1.5	40.5	0.6	5.0	2.1	1.0	4.0	2.4	4.4	4.8	2.6
			4	8.1	23.0	1.5	20.0	0.6	3.3	4.0	1.2	3.4	1.8	5.7	4.0	3.6
			6	9.1	16.0	1.7	15.0	0.8	3.4	4.2	1.0	7.2	2.3	7.6	3.5	7.0
			8	10.1	10.5	1.8	11.0	0.6	2.0	5.3	1.0	2.0	1.2	1.6	1.6	4.6
	23.50	+12.70	2	7.1	39.0	1.4	30.2	0.6	5.4	2.8	1.2	3.4	2.0	1.0	6.8	3.2
			4	8.1	21.0	1.4	18.5	0.6	3.7	3.9	1.2	1.7	2.0	1.2	3.2	4.3
			6	9.1	13.0	1.5	12.3	0.5	2.7	5.3	1.0	1.8	1.3	6.9	2.9	6.4
			8	10.1	8.3	1.6	9.0	0.5	2.4	7.0	1.1	6.6	1.3	7.1	2.8	7.3
14.0	11.98	Original	2	6.2	39.0	1.6	40.0	0.7	3.0	3.3	1.3	3.9	2.1	4.4	4.5	0.8
			4	7.2	25.0	2.1	28.8	0.8	2.3	3.4	2.0	0.2	3.9	3.2	2.2	0.4
			6	8.2	21.5	2.1	20.0	1.0	3.9	5.0	2.0	0.2	5.1	4.8	2.7	0.4
			8	9.2	17.9	2.1	16.0	1.1	3.0	6.0	1.9	0.3	3.7	5.8	2.5	0.5
	17.90	+5.92	2	6.2	40.0	1.5	36.4	0.6	3.5	2.6	1.1	0.8	1.6	2.8	2.9	1.8
			4	7.2	22.0	1.5	19.8	0.6	2.9	3.9	1.0	6.3	1.8	3.2	2.0	4.6
			6	8.2	15.7	1.8	12.8	0.9	2.3	5.1	1.0	1.9	1.5	1.7	1.9	3.7
			8	9.2	10.0	1.8	9.8	0.9	1.8	7.5	1.0	8.1	1.9	5.9	2.6	7.1
	22.50	+10.52	2	6.2	37.0	1.4	33.0	0.6	2.3	3.6	1.2	3.3	2.3	5.4	3.5	4.8
			4	7.2	19.7	1.4	17.2	0.6	3.2	3.9	1.0	5.0	1.3	1.2	2.1	4.2

(Continued)

Table 10 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal: Upstream: Pull tons	Time min	Longitudinal: Downstream: Pull tons	Time min	Upstream Transverse: Left: Pull tons	Time min	Upstream Transverse: Right: Pull tons	Time min	Downstream Transverse: Left: Pull tons	Time min	Downstream Transverse: Right: Pull tons	Time min
14.0			6	8.2	13.0	1.4	11.7	0.5	2.3	3.9	1.0	5.1	1.7	4.1	1.9	5.2
			8	9.2	6.9	1.7	7.6	0.6	1.8	7.02	1.0	6.0	1.2	5.9	2.0	6.9
11.0	13.18	Original	2	5.5	37.8	1.6	37.0	0.6	2.7	3.0	2.2	3.6	2.9	3.2	2.8	3.0
			4	6.5	25.5	2.0	24.5	0.8	1.8	1.7	1.9	0.2	2.6	1.6	1.9	0.4
			6	7.5	19.2	2.1	17.6	1.0	2.0	3.8	1.6	0.2	2.9	3.7	2.2	0.4
			8	8.5	14.0	2.2	13.9	1.1	1.6	5.4	1.3	0.3	2.3	5.6	2.1	0.5
	16.92	+3.74	2	5.5	34.0	1.5	30.5	0.6	3.2	2.0	1.0	0.4	1.8	1.3	1.6	2.0
			4	6.5	19.0	1.6	17.0	0.6	2.7	4.1	1.0	1.7	1.7	3.1	2.0	3.7
			6	7.5	12.0	1.7	12.0	0.6	2.4	4.1	1.0	4.7	2.0	5.2	2.2	3.8
			8	8.5	7.5	1.7	8.5	0.5	2.2	5.9	1.0	7.0	2.0	6.5	1.5	5.5
	22.02	+8.84	2	5.5	32.0	1.4	29.0	0.6	2.4	2.6	1.3	4.7	1.5	2.8	2.0	4.5
			4	6.5	15.8	1.4	16.0	0.6	2.0	4.2	1.0	1.7	1.5	1.3	1.5	1.9
			6	7.5	9.7	1.6	10.4	0.6	1.8	4.6	1.0	1.8	1.0	3.0	1.2	4.1
7.0	12.88	Original	2	4.4	30.2	1.7	28.0	0.7	2.0	3.4	1.4	3.7	2.6	3.2	1.7	2.5
			4	5.4	19.5	2.0	20.0	0.8	1.8	3.2	1.3	0.2	2.4	1.5	1.7	0.3
			6	6.4	15.4	2.1	14.0	1.1	1.3	0.8	1.3	0.2	1.5	1.7	1.9	0.4
	18.70	+5.82	2	4.4	28.2	1.5	25.5	0.6	1.8	2.2	1.1	0.8	2.0	1.3	2.0	2.7
			4	5.4	14.3	1.6	13.8	0.6	1.4	3.4	1.0	2.2	1.0	3.2	1.3	3.9
			6	6.4	9.2	1.6	9.4	0.9	1.3	6.0	1.0	5.4	1.6	5.8	1.1	5.6
	23.30	+10.42	2	4.4	25.0	1.4	20.5	0.5	1.8	4.1	1.6	1.2	2.5	1.2	2.1	0.6
			4	5.4	13.0	2.3	13.0	0.6	1.3	3.8	1.0	0.8	1.2	2.9	1.3	1.8
			6	6.4	7.4	1.4	8.4	0.5	1.0	1.3	1.0	0.7	1.0	1.5	1.0	0.6
5.0	13.08	Original	2	3.7	29.0	1.9	27.8	0.7	1.5	2.5	1.0	0.9	1.4	1.4	1.6	0.7
			4	4.7	18.8	2.0	16.7	1.9	1.0	0.7	1.7	0.2	2.0	1.7	1.4	0.2
			6	5.7	13.2	2.2	13.0	1.0	1.0	2.9	1.4	0.2	2.4	1.8	1.3	0.4
	18.90	+5.82	2	3.7	22.5	1.6	20.6	0.6	1.6	1.3	1.0	0.2	1.4	1.4	1.0	2.8
			4	4.7	12.8	1.7	12.5	0.7	1.5	3.1	1.0	1.0	1.5	3.3	1.0	0.8
			6	5.7	7.2	1.8	9.2	0.7	1.3	1.5	1.0	0.2	1.5	5.1	1.0	0.3

(Continued)

Table 10 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces															
					Longitudinal				Upstream Transverse				Downstream Transverse			
					Upstream		Downstream		Left		Right		Left		Right	
					Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
5.0	23.50	+10.42	2	3.7	21.8	1.4	18.2	0.6	1.3	2.2	1.1	0.8	1.2	1.2	2.0	0.6
			4	4.7	10.4	1.5	11.0	0.6	1.3	4.1	1.0	3.6	1.1	3.1	1.1	3.7
			6	5.7	5.8	1.4	7.8	0.5	1.0	3.3	1.0	2.1	1.0	3.5	1.0	2.8
3.0	12.28	Original	1	2.5	36.0	1.8	28.0	0.7	1.7	1.6	1.3	2.0	2.2	1.4	2.0	0.8
			2	3.0	26.4	2.0	21.2	0.7	1.0	1.3	1.6	1.1	2.3	1.5	1.6	0.9
			3	3.5	19.0	2.0	16.7	0.9	1.0	1.5	1.4	2.1	2.0	1.7	1.2	0.7
			4	4.0	14.0	2.1	13.6	0.8	1.0	0.9	1.2	0.3	1.0	0.8	1.0	0.5
	18.70	+6.42	1	2.5	32.0	1.5	24.6	0.6	1.0	1.2	1.0	0.8	1.0	1.3	1.0	1.3
			2	3.0	17.2	1.6	17.0	0.6	1.0	2.5	1.0	1.8	1.0	2.3	1.0	2.0
			3	3.5	--	--	--	--	--	--	--	--	--	--	--	--
			4	4.0	8.0	1.6	8.8	0.9	1.0	1.5	1.0	1.8	1.0	2.2	1.0	0.8
	23.30	+11.02	1	2.5	28.5	1.5	21.8	0.6	1.5	1.1	1.0	1.7	1.5	1.3	1.0	0.6
			2	3.0	16.0	1.5	15.0	0.7	1.7	1.4	1.0	0.8	1.7	1.3	1.0	1.9
			3	3.5	--	--	--	--	--	--	--	--	--	--	--	--
			4	4.0	4.9	1.5	7.0	[illegible]	1.0	1.0	1.0	0.8	1.0	1.7	1.0	0.6
2.0	12.48	Original	1	2.0	33.0	1.0	26.0	[illegible]	1.2	1.2	2.0	2.0	3.1	1.4	2.7	0.7
			2	2.5	23.2	2.0	18.0	1.0	1.3	1.6	1.2	0.9	1.6	1.3	1.8	1.0
			3	3.0	--	--	--	--	--	--	--	--	--	--	--	--
			4	3.5	11.6	2.0	11.5	1.1	1.0	0.7	1.1	0.2	1.4	3.6	1.2	3.1
	17.90	+5.42	1	2.0	23.0	1.6	17.2	0.6	1.2	1.2	1.1	1.8	1.2	1.3	1.5	0.6
			2	2.5	14.5	1.7	13.9	0.6	1.0	1.5	1.0	0.9	1.0	1.4	1.0	1.1
			3	3.0	--	--	--	--	--	--	--	--	--	--	--	--
			4	3.5	7.0	1.7	7.7	0.8	1.0	1.5	1.0	1.8	1.0	2.3	1.0	1.0
	22.50	+10.02	1	2.0	22.2	1.5	17.0	0.6	1.0	1.2	1.0	0.9	1.0	1.4	1.2	0.7
			2	2.5	12.0	1.5	13.6	0.6	1.0	1.5	1.0	1.9	1.0	1.5	1.0	2.1
			3	3.0	--	--	--	--	--	--	--	--	--	--	--	--
			4	3.5	5.8	1.5	6.6	0.6	1.0	1.2	1.0	0.9	1.0	1.4	1.0	0.7

(Continued)

Table 10 (Concluded)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces											
					Longitudinal				Upstream Transverse				Downstream Transverse			
					Upstream		Downstream		Left		Right		Left		Right	
					Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
1.0	12.68	Original	1	1.5	23.5	1.9	18.0	0.8	1.0	1.5	1.3	2.0	1.0	1.4	1.1	0.9
			2	2.0	15.3	2.0	12.8	0.9	1.0	0.6	1.0	1.9	1.2	1.4	1.2	0.6
			3	2.5	9.1	2.1	9.0	1.0	1.0	1.4	1.0	1.1	1.0	1.6	1.0	0.9
	17.90	+5.22	1	1.5	13.0	1.7	11.3	0.7	1.2	1.2	1.0	0.8	1.0	1.4	1.7	0.7
			2	2.0	8.3	1.8	8.5	0.7	1.0	0.6	1.0	0.9	1.0	1.3	1.3	0.7
			3	2.5	7.0	1.9	7.0	0.7	1.0	1.4	1.0	0.9	1.0	1.4	1.0	0.7
	22.50	+9.82	1	1.5	11.1	1.5	9.5	0.6	1.0	1.4	1.0	0.8	1.0	1.3	1.0	0.6
			2	2.0	6.0	1.6	5.8	0.6	1.0	1.3	1.0	0.8	1.0	2.3	1.0	0.9
			3	2.5	4.0	1.6	4.7	0.7	1.0	2.2	1.0	1.8	1.0	2.1	1.0	1.6

Table 11

Filling Characteristics, Type 15 Port Arrangement, 900- by 140-ft Ship at 30-ft Draft (2+00)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal: Upstream: Pull tons	Longitudinal: Upstream: Time min	Longitudinal: Downstream: Pull tons	Longitudinal: Downstream: Time min	Upstream Transverse: Left: Pull tons	Upstream Transverse: Left: Time min	Upstream Transverse: Right: Pull tons	Upstream Transverse: Right: Time min	Downstream Transverse: Left: Pull tons	Downstream Transverse: Left: Time min	Downstream Transverse: Right: Pull tons	Downstream Transverse: Right: Time min
18.4	12.00	-6.28	2	7.1	32.2	1.6	36.7	0.7	5.6	2.3	2.0	4.1	6.0	3.0	3.8	2.5
			4	8.1	20.3	1.8	20.0	0.7	4.2	2.9	1.0	0.7	3.5	4.1	3.2	4.4
			6	9.1	16.0	1.9	14.5	0.9	3.3	4.6	1.9	7.2	3.0	6.0	2.3	6.6
			8	10.1	13.5	1.9	12.2	1.0	3.6	5.0	1.3	9.1	3.8	6.6	2.3	5.4
	18.28	Original	2	7.1	30.6	1.5	30.0	0.6	4.0	1.7	1.2	0.7	2.1	3.0	3.8	2.1
			4	8.1	17.2	1.6	17.0	0.6	3.3	3.2	1.2	0.1	3.2	2.8	1.2	0.3
			6	9.1	13.0	1.7	11.6	0.9	2.8	4.8	1.1	0.8	2.9	4.9	1.2	1.4
			8	10.1	10.6	1.6	9.8	0.8	2.7	6.8	1.0	7.3	3.0	7.0	1.1	2.1
	26.40	+8.12	2	7.1	26.5	1.3	25.0	0.6	4.2	2.4	1.1	0.7	2.1	5.0	4.2	2.0
			4	8.1	15.0	1.4	13.0	0.6	2.7	2.6	1.0	0.6	2.0	2.4	2.2	4.3
			6	9.1	9.0	1.4	9.0	0.5	2.3	6.1	1.0	5.9	2.1	5.6	2.3	5.8
			8	10.1	6.2	1.4	6.5	0.5	2.0	5.7	1.3	8.1	2.0	7.6	1.9	4.7
14.0	14.00	-5.48	2	6.2	32.0	1.6	32.3	0.7	4.3	1.8	1.8	5.2	2.7	1.2	2.8	0.7
			4	7.2	18.0	1.8	17.5	0.6	3.0	3.3	1.0	0.8	1.6	2.0	1.9	0.7
			6	8.2	12.7	1.8	12.5	0.8	3.8	4.7	1.1	5.6	2.8	4.8	2.5	5.0
			8	9.2	10.0	1.8	10.2	0.9	2.4	4.8	1.0	0.9	1.9	3.6	1.0	0.7
	19.48	Original	2	6.2	28.0	1.4	27.0	0.6	3.8	2.6	1.5	4.7	2.9	3.2	2.5	4.9
			4	7.2	16.5	1.6	15.4	0.6	2.7	3.8	1.2	0.8	3.0	4.0	1.1	0.7
			6	8.2	11.0	1.6	10.6	0.6	2.0	4.6	1.0	4.8	2.6	4.4	1.7	4.2
			8	9.2	8.6	1.7	9.3	0.9	2.3	5.5	1.0	5.0	3.2	5.4	1.0	0.9
	25.40	+5.92	2	6.2	25.0	1.4	22.5	0.6	3.9	2.5	1.0	0.7	2.5	1.1	3.0	2.2
			4	7.2	13.4	1.4	11.9	0.5	2.5	4.1	1.0	0.7	1.3	3.2	2.0	4.4
			6	8.2	7.9	1.5	7.8	0.6	2.3	4.9	1.0	1.8	1.3	6.1	2.5	5.9
			8	9.2	5.0	1.6	6.9	0.4	1.6	5.7	1.0	6.9	1.1	7.2	1.2	6.1
11.0	14.00	-3.0	2	5.5	27.5	1.8	27.0	0.7	3.9	3.1	1.2	3.7	3.4	3.3	2.5	0.7
			4	6.5	16.8	1.8	15.0	0.8	2.9	3.6	1.0	3.8	2.0	3.5	1.5	0.7
			6	7.5	11.1	1.8	10.2	0.9	2.5	4.5	1.0	0.9	1.8	5.9	1.7	5.6

(Continued)

Table 11 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Longitudinal, Upstream, Time min	Longitudinal, Downstream, Pull tons	Longitudinal, Downstream, Time min	Upstream Transverse, Left, Pull tons	Upstream Transverse, Left, Time min	Upstream Transverse, Right, Pull tons	Upstream Transverse, Right, Time min	Downstream Transverse, Left, Pull tons	Downstream Transverse, Left, Time min	Downstream Transverse, Right, Pull tons	Downstream Transverse, Right, Time min
11.0	20.68	Original	2	5.5	23.0	1.5	25.0	0.6	1.8	2.8	1.5	0.8	1.3	1.1	2.2	0.6
			4	6.5	14.9	1.5	13.8	0.8	2.8	4.2	1.2	3.9	2.1	3.5	2.1	3.7
			6	7.5	10.0	1.7	9.6	0.6	1.0	3.9	1.1	0.8	1.8	5.5	1.4	0.9
	24.42	+3.74	2	5.5	23.0	1.4	20.8	0.6	2.7	2.4	1.0	0.8	2.2	1.1	2.0	2.9
			4	6.5	13.0	1.4	11.5	0.7	2.3	3.6	1.1	0.8	2.1	1.1	1.4	4.1
			6	7.5	7.8	1.5	6.9	0.7	1.5	3.0	1.0	0.7	1.0	4.8	1.3	3.5
7.0	15.0	-5.38	2	4.4	23.0	1.8	22.0	0.7	1.7	1.1	1.0	0.8	1.9	1.2	1.6	0.6
			4	5.4	13.3	1.8	13.2	0.8	1.7	1.4	1.0	0.8	2.6	4.4	1.4	4.9
			6	6.4	8.8	1.8	9.8	1.0	1.3	4.3	1.0	0.8	1.2	5.2	1.3	0.6
	20.38	Original	2	4.4	19.2	1.5	20.0	0.6	2.0	2.1	1.0	2.6	1.6	2.9	2.0	2.4
			4	5.4	11.5	1.6	10.8	0.7	1.5	3.9	1.2	3.4	2.0	4.5	1.2	4.3
			6	6.4	7.0	1.6	7.4	0.7	1.4	5.9	1.0	5.4	1.4	5.8	1.0	4.8
	26.20	+5.82	2	4.4	17.5	1.4	15.6	0.6	1.1	1.1	1.0	0.7	1.8	1.1	1.8	0.6
			4	5.4	9.0	1.4	8.6	0.5	1.4	3.0	1.0	0.7	1.1	1.0	1.2	0.6
			6	6.4	5.0	1.6	6.2	0.6	1.0	1.6	1.0	1.4	1.0	1.1	1.0	0.9
5.0	14.00	-6.58	2	3.7	21.8	1.8	17.0	0.7	2.4	2.0	1.2	0.8	2.2	1.3	1.9	0.6
			4	4.7	12.2	1.8	11.3	1.0	1.2	3.6	1.0	0.9	1.2	3.8	1.2	1.0
			6	5.7	8.0	1.8	8.5	1.0	1.0	1.3	1.0	0.8	1.3	0.3	1.6	0.9
	20.58	Original	2	3.7	18.0	1.5	16.2	0.7	1.2	1.3	1.0	0.7	1.2	1.1	1.2	0.9
			4	4.7	9.8	1.6	9.8	0.8	1.9	4.5	1.0	3.6	1.9	3.9	1.1	0.9
			6	5.7	5.0	1.3	6.2	0.5	1.0	1.0	1.0	1.1	1.0	0.7	1.0	1.0
	26.4	+5.82	2	3.7	15.0	1.4	12.8	0.6	1.0	1.0	1.0	0.7	1.5	1.1	1.6	0.6
			4	4.7	7.9	1.4	7.9	0.6	1.0	0.9	1.0	0.7	1.2	1.1	1.3	0.6
			6	5.7	3.9	1.4	5.5	0.6	1.0	1.2	1.0	0.7	1.0	1.1	1.0	0.6
3.0	14.00	-4.78	1	2.5	28.0	1.6	22.0	0.6	1.7	1.2	1.0	0.7	1.5	1.1	2.0	0.6
			2	3.0	16.2	1.8	12.7	0.7	1.4	1.3	1.0	0.8	1.2	1.2	1.4	0.6
			4	4.0	9.6	1.9	9.5	0.9	1.0	1.4	1.0	0.8	1.0	1.2	1.5	0.6

(Continued)

Table 11 (Concluded)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Filling Time min	Maximum Hawser Forces: Longitudinal: Upstream: Pull tons	Longitudinal: Upstream: Time min	Longitudinal: Downstream: Pull tons	Longitudinal: Downstream: Time min	Upstream Transverse: Left: Pull tons	Upstream Transverse: Left: Time min	Upstream Transverse: Right: Pull tons	Upstream Transverse: Right: Time min	Downstream Transverse: Left: Pull tons	Downstream Transverse: Left: Time min	Downstream Transverse: Right: Pull tons	Downstream Transverse: Right: Time min
3.0	19.78	Original	1	2.5	24.0	1.5	18.0	0.7	1.8	1.3	1.0	1.8	2.0	1.5	1.4	0.9
			2	3.0	14.2	1.6	12.9	0.6	1.0	1.3	1.0	0.8	1.6	1.1	1.2	0.6
			4	4.0	7.2	1.7	7.3	0.8	1.4	3.3	1.0	3.7	1.1	3.1	1.0	1.0
	26.20	+6.42	1	2.5	20.0	1.4	15.0	0.6	1.2	0.9	1.1	0.7	1.5	1.0	1.3	0.5
			2	3.0	11.1	1.4	9.6	0.6	1.0	1.2	1.0	0.7	1.5	1.0	1.9	0.5
			4	4.0	5.3	1.6	6.4	0.8	1.0	2.0	1.0	2.1	1.0	1.8	1.0	0.9
2.0	14.00	-5.98	1	2.0	22.6	1.8	17.2	0.8	1.8	1.1	1.4	0.8	2.2	1.3	3.1	0.7
			2	2.5	14.0	1.8	11.8	0.9	1.0	1.8	1.0	0.8	1.0	1.9	1.3	0.7
			4	3.5	7.1	1.8	7.6	1.0	1.0	2.0	1.0	1.8	1.0	1.4	1.3	0.8
	19.98	Original	1	2.0	18.0	1.6	13.0	0.6	1.1	0.9	1.0	0.7	1.0	1.0	2.0	0.5
			2	2.5	11.0	1.5	9.9	0.8	1.5	0.5	1.0	0.7	1.0	1.1	1.8	0.5
			4	3.5	5.7	1.6	7.3	0.9	1.0	1.3	1.0	1.0	1.5	--	--	--
	25.40	+5.42	1	2.0	15.0	1.5	13.5	0.5	1.2	0.9	1.0	1.4	1.9	1.0	1.2	0.5
			2	2.5	8.6	1.9	9.0	0.6	1.0	1.3	1.0	0.7	1.1	7.1	1.3	0.2
			4	3.5	4.6	1.5	6.0	0.8	1.0	1.6	1.0	2.1	1.0	1.9	1.0	0.6
1.0	15.0	-5.18	1	1.5	13.6	1.8	10.7	0.6	1.1	1.4	1.1	0.8	1.3	1.2	1.5	0.6
			2	2.0	10.0	1.8	8.5	0.9	1.0	1.1	1.0	0.8	1.2	1.2	1.6	0.7
			4	3.0	6.5	1.9	6.0	1.0	1.0	1.4	1.0	3.0	1.0	2.1	1.0	1.0
	20.18	Original	1	1.5	11.0	1.5	9.0	0.7	1.0	0.9	1.0	0.8	1.0	1.3	1.0	0.9
			2	2.0	7.2	1.7	6.8	0.6	1.0	1.2	1.0	1.4	1.0	1.8	1.0	1.5
			4	3.0	3.7	1.6	5.0	0.7	1.0	1.3	1.0	0.8	1.0	1.1	1.0	0.7
	25.40	+5.22	1	1.5	8.4	1.4	8.4	0.5	1.0	0.9	1.0	0.7	1.0	1.1	1.3	0.6
			2	2.0	5.8	1.4	6.3	0.6	1.0	1.2	1.0	1.5	1.0	1.1	1.0	0.6
			4	3.0	2.3	2.9	3.0	0.6	1.0	1.7	1.0	0.8	1.0	3.1	1.0	0.7

(Sheet 3 of 3)

Table 12

Emptying Characteristics, Type 15 Port Arrangement, 900- by 140-ft Ship at 45-ft Draft (2+00)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces											
					Longitudinal				Upstream Transverse				Downstream Transverse			
					Upstream		Downstream		Left		Right		Left		Right	
					Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
18.4	3.28	Original	4	8.7	17.0	1.6	38.0	0.7	2.0	1.5	2.0	0.8	3.7	1.3	3.3	0.6
			6	9.7	12.5	1.6	26.0	0.7	1.5	0.5	1.7	0.9	2.3	1.4	2.2	0.6
			8	10.7	9.2	1.6	19 5	0.7	1.5	1.5	1.0	0.8	1.8	0.3	1.5	1.1
	11.4	+8.12	4	8.7	21.0	1.4	32.5	0.5	2.0	1.0	1.3	1.7	2.5	1.2	1.7	0.5
			6	9.7	15.5	1.4	22.6	0.5	1.6	1.0	1.6	1.6	2.3	1.2	1.5	0.5
			8	10.7	11.5	1.3	18.0	0.5	1.5	4.0	1.7	1.7	2.2	1.2	1.4	0.5
	16.0	+12.72	4	8.7	17.8	1.3	28.5	0.5	2.0	1.2	1.0	0.7	1.5	1.3	2.2	0.6
			6	9.7	13.0	1.4	21.0	0.5	1.3	1.1	1.0	0.7	1.4	1.3	1.8	0.6
			8	10.7	7.6	1.3	17.3	0.5	1.2	2.5	1.0	0.7	1.5	4.2	1.0	0.6
	19.0	+15.72	4	8.7	17.3	1.3	28.8	0.5	2.3	1.2	1.9	0.8	2.2	1.3	3.2	0.6
			6	9.7	10.8	1.4	2.0	0.5	1.0	1.1	1.0	0.7	1.2	1.3	1.3	0.5
			8	10.7	9.0	4.3	16.0	0.5	1.0	1.1	1.0	0.7	1.0	1.2	1.5	0.5
	22.0	+18.72	4	8.7	17.4	1.3	25.5	0.5	3.3	1.1	3.0	0.8	4.0	1.4	4.6	0.6
			6	9.7	10.0	1.3	19.5	0.5	1.2	1.1	1.0	0.7	1.4	1.3	1.5	0.6
			8	10.7	8.6	1.2	14.5	0.4	1.5	1.1	2.0	1.7	2.0	1.3	3.0	0.5
	26.0	+22.72	4	8.7	14.0	1.2	24.0	0.5	2.0	1.1	2.6	1.8	2.6	1.3	4.0	1.6
			6	9.7	9.2	1.3	18.0	0.5	1.8	1.1	1.8	0.8	1.8	1.3	3.2	1.6
			8	10.7	7.2	1.2	13.0	0.5	1.0	1.1	1.2	0.8	1.0	1.2	1.5	0.6
14.0	4.48	Original	4	7.7	14.5	1.7	32.0	0.7	2.0	1.3	1.7	0.9	3.0	1.4	2.0	0.6
			6	8.7	9.5	1.8	22.7	0.7	1.6	0.5	1.2	0.8	1.9	0.3	1.9	0.6
			8	9.7	7.5	1.8	19.0	0.8	1.6	0.6	1.3	0.9	1.9	0.4	2.0	1.1
	15.00	+10.52	4	7.7	18.5	1.4	26.0	0.6	1.8	1.1	0.4	0.8	2.4	1.2	2.3	0.6
			6	8.7	12.0	1.4	18.3	0.6	1.3	1.1	1.7	0.8	2.4	1.2	2.3	0.6
			8	9.7	18.7	1.4	15.2	0.6	1.0	1.1	1.6	0.8	2.2	1.3	1.7	0.6

(Continued)

Table 12 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Longitudinal, Upstream, Time min	Longitudinal, Downstream, Pull tons	Longitudinal, Downstream, Time min	Upstream Transverse, Left, Pull tons	Upstream Transverse, Left, Time min	Upstream Transverse, Right, Pull tons	Upstream Transverse, Right, Time min	Downstream Transverse, Left, Pull tons	Downstream Transverse, Left, Time min	Downstream Transverse, Right, Pull tons	Downstream Transverse, Right, Time min
14.0	19.00	+14.52	4	7.7	17.5	1.5	24.0	0.5	2.2	1.2	2.5	0.8	3.0	1.3	3.5	0.6
			6	8.7	11.5	1.4	18.2	0.6	1.3	1.1	1.6	0.8	1.8	1.3	2.0	0.6
			8	9.7	7.8	1.4	15.1	0.5	1.3	2.5	1.0	0.8	2.5	1.3	1.0	3.5
	25.00	+20.52	4	7.7	15.0	1.3	21.8	0.5	1.7	1.1	1.5	0.8	1.7	1.3	3.0	0.6
			6	8.7	10.0	1.3	17.0	0.5	1.3	1.0	1.3	0.8	1.6	1.3	2.0	0.5
			8	9.7	8.5	1.3	15.0	0.5	1.0	1.3	1.1	0.7	1.1	1.1	1.7	1.8
11.0	5.68	Original	4	6.8	13.0	2.0	32.2	0.7	2.2	0.5	1.9	0.9	3.0	1.4	2.6	0.6
			6	7.8	9.2	1.9	22.8	0.8	2.0	0.6	1.2	0.9	2.0	0.3	1.8	0.6
			8	8.8	7.8	2.0	18.2	1.2	1.7	0.6	1.2	0.8	1.8	0.4	2.3	1.1
	9.40	+3.72	4	6.8	15.7	1.4	27.8	0.6	2.3	1.9	1.9	0.9	2.4	1.4	3.0	0.7
			6	7.8	11.0	1.5	21.5	0.6	1.1	1.4	1.5	0.7	1.9	1.3	1.1	0.5
			8	8.8	7.8	1.5	16.3	0.6	1.5	1.3	1.0	0.9	7.1	1.4	1.8	0.8
	14.52	+8.84	4	6.8	15.2	1.3	23.9	0.5	2.6	1.2	2.2	0.9	3.4	1.4	3.3	0.6
			6	7.8	10.5	1.4	19.8	0.5	1.1	1.2	1.1	0.8	1.8	1.3	1.5	0.7
			8	8.8	7.8	1.4	15.0	0.5	1.2	5.7	1.2	3.9	1.9	1.2	1.0	1.9
	17.52	+11.84	4	6.8	18.6	1.3	22.9	2.1	3.3	4.2	3.3	1.8	3.9	1.4	5.0	0.6
			6	7.8	10.3	1.4	17.9	0.6	1.2	1.2	1.5	0.8	1.8	1.3	2.0	0.6
			8	8.8	7.7	1.4	13.4	0.5	1.2	4.4	1.2	1.8	1.5	1.2	1.7	4.9
	20.52	+14.84	4	6.8	15.8	1.3	21.8	0.5	3.0	1.1	3.9	1.4	3.2	1.9	4.5	0.6
			6	7.8	9.8	1.3	17.0	0.5	1.2	1.4	1.2	0.8	1.3	1.2	1.9	0.6
			8	8.8	7.5	1.3	12.6	0.5	1.8	1.1	1.1	0.8	1.9	1.3	1.5	0.6
	24.52	+18.84	4	6.8	15.8	1.4	21.8	0.5	2.0	1.2	1.2	0.8	2.0	1.4	2.6	0.7
			6	7.8	9.0	1.3	17.0	0.5	1.2	1.1	1.2	0.8	1.8	1.3	1.8	0.6
			8	8.8	5.6	1.3	12.0	0.5	1.4	5.2	1.0	1.7	1.4	1.2	1.2	4.7
7.0	5.38	Original	4	5.8	12.5	2.0	29.5	1.2	1.9	0.5	1.7	0.9	2.4	0.3	2.3	1.1
			6	6.8	9.0	2.1	20.7	1.2	1.6	0.6	1.3	0.9	2.0	0.4	2.0	1.1
			8	7.8	6.0	2.1	13.5	1.2	1.4	0.8	1.2	0.9	1.9	0.4	2.0	1.1

(Continued)

Table 12 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance + ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal Upstream Pull tons	Longitudinal Upstream Time min	Longitudinal Downstream Pull tons	Longitudinal Downstream Time min	Upstream Transverse Left Pull tons	Upstream Transverse Left Time min	Upstream Transverse Right Pull tons	Upstream Transverse Right Time min	Downstream Transverse Left Pull tons	Downstream Transverse Left Time min	Downstream Transverse Right Pull tons	Downstream Transverse Right Time min
7.0	7.88	+2.5	4	5.8	11.2	2.0	27.8	0.6	1.0	3.6	1.4	4.5	1.3	3.9	1.3	3.0
			6	6.8	9.2	1.9	20.0	0.6	1.0	3.8	1.0	1.9	1.4	1.5	1.3	3.0
			8	7.8	7.6	2.0	15.8	0.8	1.0	2.7	1.3	2.0	1.4	2.5	1.2	4.6
	11.20	+5.82	4	5.8	13.0	1.7	26.3	0.6	1.0	1.5	1.3	1.9	1.7	1.3	1.0	2.1
			6	6.8	7.3	1.9	17.9	0.6	1.0	3.4	1.3	1.9	1.6	4.4	1.1	1.9
			8	7.8	6.2	1.9	14.6	0.6	1.0	1.2	1.1	0.8	1.5	1.3	1.2	0.6
	15.8	+10.42	4	5.8	12.8	1.5	22.6	0.6	1.6	1.2	1.5	1.9	2.5	1.4	1.5	0.7
			6	6.8	8.0	1.5	16.3	0.6	1.6	1.2	1.3	0.9	2.2	1.4	1.7	0.7
			8	7.8	6.8	1.4	14.0	0.6	1.0	1.5	1.0	0.7	1.6	1.3	1.0	0.5
	18.8	+13.42	4	5.8	11.2	1.5	21.6	0.6	1.3	1.3	1.3	2.0	1.6	1.5	1.6	0.7
			6	6.8	6.6	1.4	15.9	0.6	1.0	1.2	1.7	1.8	1.7	1.3	2.0	0.7
			8	7.8	6.0	1.4	12.7	0.6	1.0	1.1	1.0	1.8	1.0	1.2	1.0	0.6
	21.8	+16.42	4	5.8	12.0	1.4	20.7	0.6	1.8	1.3	1.0	1.7	1.0	1.2	1.8	1.9
			6	6.8	6.4	1.4	14.0	0.6	1.0	1.4	1.0	1.7	1.3	1.2	1.2	0.6
			8	7.8	5.3	1.4	11.0	0.5	1.0	1.3	1.0	0.8	1.0	1.3	1.1	0.6
	25.8	+20.42	4	5.8	12.9	1.4	18.4	0.6	1.9	1.1	1.0	1.8	1.8	1.4	1.5	0.6
			6	6.8	8.0	1.4	12.9	0.6	1.0	1.2	1.0	1.3	1.8	4.2	1.0	0.7
			8	7.8	6.3	1.3	11.2	0.5	1.0	4.5	1.0	6.2	1.0	4.3	1.0	2.0
5.0	5.58	Original	3	4.2	20.0	2.0	39.0	0.7	2.6	1.6	1.8	0.8	2.9	0.3	2.8	1.0
			4	4.7	11.5	1.9	28.3	0.8	2.0	0.5	1.6	0.9	2.2	0.3	2.5	1.0
			6	5.7	8.2	2.0	20.5	1.1	2.0	0.5	1.2	0.8	2.2	0.4	2.3	1.0
	11.4	+5.82	3	4.2	22.5	3.9	32.9	0.6	1.9	1.4	1.2	1.9	1.2	1.4	2.0	0.8
			4	4.7	14.8	3.9	23.0	0.6	1.0	1.5	1.4	0.8	1.6	1.4	1.7	3.0
			6	5.7	12.9	5.3	16.1	0.6	1.0	1.3	1.5	0.8	1.6	1.4	1.7	0.6
	16.0	+10.42	3	4.2	17.4	3.7	28.4	0.6	1.7	1.3	1.6	2.0	2.0	1.4	2.4	0.7
			4	4.7	8.5	1.6	20.5	0.6	1.0	1.4	1.1	0.7	1.0	1.3	1.4	0.9
			6	5.7	5.8	1.6	14.6	0.6	1.0	2.3	1.2	0.8	1.2	1.4	1.2	2.8

(Continued)

Table 12 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream Pull tons	Longitudinal: Upstream Time min	Longitudinal: Downstream Pull tons	Longitudinal: Downstream Time min	Upstream Transverse: Left Pull tons	Upstream Transverse: Left Time min	Upstream Transverse: Right Pull tons	Upstream Transverse: Right Time min	Downstream Transverse: Left Pull tons	Downstream Transverse: Left Time min	Downstream Transverse: Right Pull tons	Downstream Transverse: Right Time min
5.0	22.0	+16.42	3	4.2	14.6	1.4	25.2	0.6	2.5	1.3	1.0	0.9	2.0	1.4	2.0	0.7
			4	4.7	7.0	1.4	17.6	0.6	1.2	2.4	1.0	1.8	1.2	0.3	1.0	2.8
			6	5.7	6.1	1.4	11.2	0.6	1.0	2.4	1.0	1.9	1.0	3.3	1.0	2.9
	26.0	+20.42	3	4.2	12.0	1.4	22.0	0.6	1.1	1.4	1.1	0.7	1.2	1.3	1.4	2.0
			4	4.7	7.5	1.4	18.0	0.6	1.0	1.4	1.0	0.7	1.4	1.2	1.3	1.9
			6	5.7	5.7	1.3	11.0	0.6	1.0	1.4	1.0	0.7	1.2	1.2	1.3	1.9
3.0	4.78	Original	2	3.3	25.0	2.0	46.0	1.0	2.0	0.4	1.1	0.8	2.0	0.3	2.0	0.9
			4	4.3	9.2	2.0	26.5	1.1	2.6	1.7	1.2	0.9	2.3	0.6	3.0	1.1
			6	5.3	6.2	2.2	18.5	1.2	1.8	0.5	1.1	0.8	2.0	0.3	3.0	1.1
	7.88	+3.1	2	3.3	28.0	2.3	34.0	0.7	1.5	1.7	1.0	0.7	1.0	1.0	2.2	1.0
			4	4.3	12.0	2.3	21.0	0.7	1.0	0.6	1.0	0.9	1.1	1.6	1.3	3.3
			6	5.3	9.0	2.1	16.0	1.1	1.0	1.6	1.2	0.8	1.5	1.5	1.0	1.1
	11.20	+6.42	2	3.3	23.0	2.0	29.8	0.7	1.2	1.5	1.2	1.9	1.3	1.4	2.0	2.1
			4	4.3	10.7	2.0	18.0	0.7	1.2	1.6	1.0	0.8	1.6	1.4	1.3	1.0
			6	5.3	7.1	2.0	13.3	0.7	1.0	1.6	1.1	0.9	1.5	1.5	1.2	0.6
	15.80	11.02	2	3.3	18.0	1.7	25.8	0.6	1.0	1.4	1.0	0.7	1.3	1.3	1.5	0.8
			4	4.3	9.0	1.6	15.6	0.6	1.0	1.5	1.0	0.8	1.0	1.3	1.0	0.9
			6	5.3	5.5	1.6	11.5	0.6	1.0	1.2	1.0	0.8	1.0	1.3	1.0	0.6
	18.80	14.02	2	3.3	13.0	1.6	22.0	0.6	1.4	1.4	1.2	1.8	1.6	1.3	1.3	0.8
			4	4.3	7.2	1.6	13.0	0.6	1.0	1.2	1.0	0.8	1.1	1.4	1.0	0.9
			6	5.3	5.0	1.4	9.9	0.6	1.0	1.2	1.0	0.8	1.0	1.3	1.0	0.7
	25.80	21.02	2	3.3	12.2	1.4	18.5	1.6	1.6	1.3	1.1	1.7	1.2	1.2	2.0	0.8
			4	4.3	6.1	1.4	10.5	0.6	1.0	1.4	1.0	0.8	1.0	1.3	1.0	2.0
			6	5.3	5.0	1.3	7.9	0.5	1.0	1.4	1.0	3.4	1.0	1.2	1.0	0.9
2.0	4.98	Original	1	2.2	37.0	1.3	44.0	0.6	2.1	1.2	2.1	0.7	3.9	1.6	4.0	0.8
			2	2.7	23.0	1.6	34.0	0.8	1.6	1.2	1.0	0.7	2.3	0.2	2.5	0.7
			4	3.7	8.3	1.8	22.3	0.7	2.0	1.4	1.2	0.7	2.5	2.6	2.7	0.9

(Continued)

Table 12 (Concluded)

					Maximum Hawser Forces											
					Longitudinal				Upstream Transverse				Downstream Transverse			
					Upstream		Downstream		Left		Right		Left		Right	
Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
2.0	10.4	+5.42	1	2.2	34.0	2.1	33.5	0.7	2.0	1.5	1.9	1.0	2.5	1.6	3.0	0.8
			2	2.7	19.8	2.1	23.5	0.7	1.0	1.7	1.0	0.9	1.6	1.5	1.5	0.7
			4	3.7	7.2	2.1	15.0	1.1	1.0	1.7	1.0	0.9	1.4	1.5	1.0	1.6
	15.00	10.02	1	2.2	28.0	1.8	29.0	0.7	1.1	1.5	1.8	0.7	1.6	1.3	2.0	0.9
			2	2.7	13.5	2.1	20.0	0.7	1.0	1.5	1.2	0.8	1.0	1.3	1.5	2.1
			4	3.7	7.8	3.1	13.0	0.6	1.0	1.5	1.0	0.8	1.0	1.4	1.2	0.9
	19.00	+14.02	1	2.2	23.5	1.5	29.0	0.6	2.2	1.3	1.8	1.0	2.2	1.5	2.7	0.7
			2	2.7	10.6	1.5	20.0	0.6	1.0	1.2	1.0	0.8	1.5	1.4	1.5	0.6
			4	3.7	5.8	1.5	12.0	0.6	1.0	2.4	1.5	1.9	1.0	1.4	1.2	1.7
1.0	5.18	Original	1	1.6	29.5	1.3	29.5	0.6	1.8	1.0	1.4	1.5	1.9	0.2	1.8	0.7
			2	2.1	20.0	1.6	24.5	0.8	1.6	0.4	1.0	0.6	1.8	0.2	2.2	0.8
			4	3.1	7.4	2.2	16.8	1.0	1.3	0.5	1.0	0.7	2.0	0.2	2.7	1.0
	10.4	+5.22	1	1.6	25.5	2.1	24.0	0.7	1.2	1.7	1.0	1.0	1.0	1.5	1.1	1.0
			2	2.1	15.7	2.2	17.9	1.1	1.0	1.7	1.0	0.9	1.0	1.6	1.0	1.1
			4	3.1	6.5	2.0	11.8	9.1	1.0	1.6	1.0	0.8	1.0	1.4	1.1	1.1
	15.0	+9.82	1	1.6	17.8	1.8	20.0	0.7	1.2	1.5	1.0	1.0	1.0	1.3	1.0	0.9
			2	2.1	11.0	1.9	14.3	0.6	1.1	2.6	1.0	1.9	1.0	1.4	1.0	2.1
			4	3.1	6.4	3.7	10.3	0.6	1.0	1.6	1.0	3.0	1.0	3.6	1.0	1.0
	19.0	+13.82	1	1.6	16.0	1.7	19.0	0.7	1.2	1.5	1.1	1.9	1.0	1.4	1.7	2.1
			2	2.1	10.0	1.5	13.5	0.6	1.0	1.5	1.0	0.9	1.3	1.4	1.4	0.8
			4	3.1	5.0	3.2	9.5	0.6	1.0	1.5	1.2	0.7	1.2	1.3	1.0	0.9
	25.0	+19.82	1	1.6	14.8	1.5	18.4	0.6	1.0	1.4	1.0	0.7	1.0	1.1	1.4	1.8
			2	2.1	8.6	1.5	13.1	0.6	1.0	1.3	1.0	0.8	1.0	1.3	1.4	0.8
			4	3.1	5.0	3.0	7.7	0.6	1.0	1.4	1.0	1.7	1.0	1.2	1.0	2.6

(Sheet 5 of 5)

Table 13

Emptying Characteristics, Type 15 Port Arrangement, 900- by 150-ft Ship at 37.5-ft Draft (2+00)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream: Pull tons	Longitudinal: Upstream: Time min	Longitudinal: Downstream: Pull tons	Longitudinal: Downstream: Time min	Upstream Transverse: Left: Pull tons	Upstream Transverse: Left: Time min	Upstream Transverse: Right: Pull tons	Upstream Transverse: Right: Time min	Downstream Transverse: Left: Pull tons	Downstream Transverse: Left: Time min	Downstream Transverse: Right: Pull tons	Downstream Transverse: Right: Time min
18.4	10.78	Original	2	7.7	23.0	3.0	45.0	0.6	2.0	1.1	1.7	0.6	2.0	1.0	2.3	0.6
			4	8.7	18.0	1.4	30.0	0.7	2.0	1.1	2.7	1.7	3.5	1.2	2.6	1.5
			6	9.7	14.0	1.5	21.5	0.7	2.3	1.2	2.0	0.9	3.0	1.3	2.0	1.6
			8	10.7	10.0	1.4	15.5	0.7	1.9	1.1	2.0	0.9	3.0	1.3	2.0	0.7
	15.38	+4.6	2	7.7	25.0	2.6	41.5	0.6	1.6	1.1	1.5	0.6	2.5	1.0	2.8	1.6
			4	8.7	15.0	1.3	24.2	0.5	1.5	1.0	2.0	0.7	1.6	1.1	2.6	3.1
			6	9.7	10.0	1.2	16.9	0.5	1.2	1.0	1.3	0.6	2.0	1.1	1.5	0.9
			8	10.7	8.0	1.2	12.9	0.5	1.2	5.2	1.2	0.6	1.6	1.1	1.7	6.5
	18.90	+8.1	2	7.7	26.5	2.5	40.0	0.6	1.7	1.0	1.5	0.6	1.7	1.0	2.0	0.6
			4	8.7	13.3	1.3	23.0	0.5	1.2	2.1	1.0	0.6	1.8	5.4	1.6	1.7
			6	9.7	8.2	1.2	16.2	0.5	1.3	1.0	1.3	0.7	2.0	1.1	1.6	0.5
			8	10.7	6.2	1.2	12.5	0.5	1.0	1.2	1.4	1.4	1.8	1.1	1.8	0.6
	23.50	+12.7	2	7.7	30.0	2.4	37.8	0.5	2.4	1.0	1.5	0.6	2.1	3.5	3.0	0.5
			4	8.7	11.5	1.2	21.5	0.5	1.0	1.0	1.0	0.7	1.0	1.1	1.7	0.6
			6	9.7	7.8	1.2	15.0	0.5	1.0	5.8	1.1	1.4	1.3	3.5	1.5	6.2
			8	10.7	5.7	1.2	11.6	0.5	1.0	1.7	1.0	1.4	1.0	1.1	1.2	2.9
14.0	11.98	Original	2	6.7	22.5	3.1	42.0	0.6	1.6	1.1	1.8	0.7	2.6	1.1	2.3	0.7
			4	7.7	16.0	1.4	28.0	0.7	2.2	2.8	2.5	0.8	3.6	1.3	2.8	0.6
			6	8.7	12.0	1.4	20.2	0.7	1.5	1.1	2.2	1.7	2.9	1.3	2.1	0.6
			8	9.7	9.8	1.5	15.0	0.8	1.3	1.7	1.7	0.9	2.6	1.7	1.0	0.7
	17.90	+5.92	2	6.7	23.0	2.7	40.0	0.6	1.2	1.1	1.3	3.3	2.1	1.1	1.8	3.1
			4	7.7	14.9	1.4	23.4	0.6	1.0	1.2	1.4	1.5	1.9	1.1	2.0	3.3
			6	8.7	10.2	1.3	16.0	0.5	1.0	1.0	1.2	0.7	1.7	1.1	1.2	2.2
			8	9.7	7.0	1.2	12.4	0.5	1.0	1.0	1.1	0.6	1.8	1.1	1.3	0.5
	22.50	+10.52	2	6.7	25.0	2.6	35.5	0.6	1.3	1.1	1.2	0.6	1.9	1.0	1.9	1.6
			4	7.7	12.8	1.2	20.5	0.5	1.2	1.0	1.1	0.6	1.2	1.1	2.0	3.0

(Continued)

Table 13 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces											
					Longitudinal				Upstream Transverse				Downstream Transverse			
					Upstream		Downstream		Left		Right		Left		Right	
					Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
14.0			6	8.7	8.7	1.2	14.5	0.5	1.0	3.7	1.0	0.7	1.0	1.1	1.1	3.2
			8	9.7	6.5	1.1	11.2	0.5	1.2	3.6	1.0	3.9	1.6	3.5	1.5	4.1
11.00	13.8	Original	2	5.8	25.0	3.1	40.5	0.6	1.2	1.1	1.4	0.6	2.3	2.9	1.9	0.6
			4	6.8	13.4	5.3	24.0	0.6	1.9	1.0	2.1	0.8	3.0	1.3	2.6	0.7
			6	7.8	8.4	1.5	17.5	0.7	1.7	1.5	1.7	3.5	2.9	1.3	1.9	3.7
			8	8.8	7.2	1.5	13.3	0.8	1.3	0.7	1.2	0.9	2.1	1.3	2.0	0.7
	16.92	+3.74	2	5.8	24.0	3.1	37.0	0.6	2.0	1.2	1.3	0.6	2.5	1.1	1.4	1.7
			4	6.8	12.0	4.5	21.0	0.5	1.8	1.0	1.3	0.7	1.8	2.8	2.2	0.6
			6	7.8	7.8	1.2	14.5	0.5	1.1	1.0	1.0	0.6	1.3	1.1	1.4	0.6
			8	8.8	5.9	1.2	12.0	0.5	1.1	5.4	1.0	4.8	1.2	4.4	1.4	5.0
	22.02	+8.84	2	5.8	21.5	2.9	35.5	0.6	1.5	1.1	1.2	0.7	1.8	1.1	1.6	0.6
			4	6.8	10.2	1.3	19.0	0.5	1.3	1.1	1.5	0.7	2.0	1.1	1.6	0.6
			6	7.8	7.8	1.3	13.9	0.5	1.0	1.0	1.2	0.7	1.6	1.1	1.6	0.6
7.0	12.88	Original	2	4.8	20.0	3.6	35.5	0.6	1.0	2.8	2.0	3.5	2.5	3.0	1.7	2.3
			4	5.8	12.8	1.8	22.2	0.7	1.3	1.1	1.8	0.8	2.8	1.3	2.0	0.7
			6	6.8	9.7	1.9	15.3	0.8	1.6	0.7	1.6	1.8	2.5	1.4	1.7	0.7
	18.70	+5.82	2	4.8	18.0	1.4	30.5	0.6	1.3	1.2	1.5	0.7	2.2	3.0	1.9	0.7
			4	5.8	9.3	1.4	18.0	0.6	1.0	1.1	1.4	0.7	1.5	1.2	1.7	0.6
			6	6.8	7.8	1.3	12.5	0.5	1.0	2.7	1.3	2.4	1.4	2.9	1.2	2.2
	23.30	+10.42	2	4.8	18.0	1.3	28.5	0.5	2.0	1.0	1.7	1.4	2.3	1.0	2.1	0.6
			4	5.8	8.3	1.3	16.5	0.5	1.2	1.0	1.0	0.7	1.6	1.1	1.3	0.6
			6	6.8	7.2	1.2	10.6	0.6	1.1	1.0	1.0	0.5	1.3	1.1	1.2	0.6
5.0	13.08	Original	2	4.2	18.0	3.6	33.0	0.6	1.4	1.2	1.2	1.7	1.6	1.2	1.5	1.6
			4	5.2	11.0	1.9	19.5	0.7	1.0	1.2	1.8	1.8	2.0	1.4	2.2	2.7
			6	6.2	8.8	1.9	14.6	0.7	1.3	3.4	1.6	0.9	2.0	1.4	1.8	2.9

(Continued)

Table 13 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream Pull tons	Longitudinal: Upstream Time min	Longitudinal: Downstream Pull tons	Longitudinal: Downstream Time min	Upstream Transverse: Left Pull tons	Upstream Transverse: Left Time min	Upstream Transverse: Right Pull tons	Upstream Transverse: Right Time min	Downstream Transverse: Left Pull tons	Downstream Transverse: Left Time min	Downstream Transverse: Right Pull tons	Downstream Transverse: Right Time min
5.0	18.90	+5.82	2	4.2	15.5	3.2	26.0	0.6	1.8	1.1	1.2	1.7	2.0	1.2	1.6	0.6
			4	5.2	7.4	1.4	16.5	0.6	1.3	1.1	1.0	0.7	1.6	1.2	1.4	0.6
			6	6.2	5.9	4.8	11.6	0.6	1.1	1.1	1.0	0.7	1.5	1.2	1.0	0.5
	23.50	+10.42	2	4.2	14.5	3.0	22.8	0.6	1.2	1.2	1.2	1.6	1.6	2.8	1.6	0.7
			4	5.2	7.9	4.5	15.0	0.5	1.0	2.7	1.5	3.3	1.3	2.8	1.5	3.5
			6	6.2	6.3	1.3	11.3	0.5	1.0	3.8	1.0	3.2	1.0	3.6	1.0	3.4
3.0	12.28	Original	1	2.8	33.0	1.9	38.0	0.6	1.2	1.2	1.7	2.7	2.0	1.3	2.2	2.9
			2	3.3	22.5	2.0	27.5	0.7	1.1	3.5	1.3	0.8	1.8	1.3	1.6	3.1
			3	3.8	15.8	2.0	21.7	1.1	1.0	1.2	1.8	1.8	2.0	1.4	2.2	0.7
			4	4.3	9.8	2.0	16.8	0.7	1.0	0.6	1.0	1.8	1.2	1.4	1.2	0.6
	18.70	+6.42	1	2.8	27.5	1.5	32.0	0.6	1.6	1.1	1.5	1.6	2.2	3.0	1.8	2.4
			2	3.3	12.6	1.5	22.0	0.6	1.4	1.3	1.2	0.6	1.4	1.1	1.4	0.8
			3	3.8	--	--	--	--	--	--	--	--	--	--	--	--
			4	4.3	6.1	1.4	13.4	0.6	1.0	1.3	1.0	0.7	1.0	1.2	1.0	0.5
	23.30	+11.02	1	2.8	24.5	1.5	29.2	0.6	2.0	1.2	1.0	0.7	1.6	1.1	1.6	0.7
			2	3.3	11.2	1.4	19.8	0.6	1.8	2.0	1.0	0.7	2.0	2.0	1.5	0.6
			3	3.8	--	--	--	--	--	--	--	--	--	--	--	--
			4	4.3	5.2	1.3	12.2	0.6	1.0	1.2	1.0	0.7	1.1	1.2	1.0	0.6
2.0	12.48	Original	1	2.2	33.0	2.0	32.0	0.7	1.1	1.3	1.8	1.9	2.3	1.4	1.9	0.8
			2	2.7	19.0	2.0	22.0	0.7	1.3	1.2	1.4	1.9	2.0	1.4	2.2	0.6
			4	3.7	8.5	2.0	12.0	0.9	1.0	3.4	1.2	0.9	1.2	1.4	1.0	0.6
	17.90	+5.42	1	2.2	20.0	1.7	25.0	0.6	1.0	1.2	1.0	0.7	1.4	1.2	1.0	0.7
			2	2.7	11.2	1.7	16.5	0.6	1.0	1.2	1.1	0.7	1.4	1.2	1.0	0.6
			4	3.7	4.6	1.7	10.5	0.6	1.0	1.3	1.0	0.7	1.5	2.9	1.0	0.8
	22.50	+10.02	1	2.2	20.0	1.5	23.0	0.6	1.3	1.2	1.2	0.7	1.2	1.1	1.6	0.8
			2	2.7	10.0	1.5	16.0	0.6	1.0	2.1	1.2	1.6	1.2	1.2	1.2	1.5
			4	3.7	4.3	1.4	10.0	0.6	1.0	2.8	1.0	3.5	1.0	3.0	1.3	2.3

(Continued)

Table 13 (Concluded)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal: Upstream: Pull tons	Longitudinal: Upstream: Time min	Longitudinal: Downstream: Pull tons	Longitudinal: Downstream: Time min	Upstream Transverse: Left: Pull tons	Upstream Transverse: Left: Time min	Upstream Transverse: Right: Pull tons	Upstream Transverse: Right: Time min	Downstream Transverse: Left: Pull tons	Downstream Transverse: Left: Time min	Downstream Transverse: Right: Pull tons	Downstream Transverse: Right: Time min
1.0	12.68	Original	1	1.6	24.0	2.0	23.3	0.7	1.0	2.6	1.0	1.8	1.3	1.3	1.0	1.0
			2	2.1	15.0	2.0	15.9	1.1	1.0	1.2	1.0	1.9	1.2	1.4	1.2	0.6
			3	2.6	9.3	2.0	11.9	1.1	1.0	1.3	1.0	0.8	1.0	1.4	1.0	0.7
			4	3.1	5.2	2.1	11.0	0.8	1.0	2.5	1.0	2.2	1.0	2.8	1.0	2.9
	17.90	+5.22	1	1.6	14.0	1.8	18.0	0.6	1.0	1.3	1.0	0.7	1.0	1.2	1.6	0.9
			2	2.1	7.9	1.8	12.0	0.6	1.3	1.3	1.0	0.7	1.0	1.2	1.8	0.8
			3	2.6	5.9	1.7	10.0	0.6	1.0	1.3	1.0	1.6	1.0	1.1	1.4	0.8
			4	3.1	--	--	--	--	--	--	--	--	--	--	--	--
	22.50	+9.82	1	1.6	11.4	1.4	14.8	0.6	1.2	1.3	1.0	0.7	1.3	2.0	1.0	0.8
			2	2.1	6.1	1.4	9.8	0.6	1.0	1.2	1.0	1.6	1.2	1.2	0.7	0.7
			3	2.6	3.5	1.4	8.5	0.6	1.0	1.8	1.0	1.6	1.0	1.1	1.0	0.8

(Sheet 4 of 4)

Table 14

Emptying Characteristics, Type 15 Port Arrangement, 900- by 140-ft Ship at 30-ft Draft (2+00)

					Maximum Hawser Forces											
					Longitudinal				Upstream Transverse				Downstream Transverse			
					Upstream		Downstream		Left		Right		Left		Right	
Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min	Pull tons	Time min
18.4	12.00	-6.28	2	7.7	25.5	2.8	34.0	0.6	1.7	0.9	1.9	0.6	2.2	1.0	2.0	1.2
			4	8.7	13.6	1.3	19.5	0.6	1.2	1.1	1.7	0.6	2.0	0.9	1.7	2.0
			6	9.7	8.5	1.2	13.9	0.5	1.2	1.0	1.0	0.6	1.3	0.9	1.6	4.9
			8	10.7	6.1	1.2	11.0	0.5	1.3	3.0	1.1	0.6	1.7	3.8	1.4	3.4
	18.28	Original	2	7.7	22.0	2.6	30.0	0.5	1.8	1.0	2.1	0.5	2.2	0.9	2.5	0.6
			4	8.7	13.6	1.2	18.2	0.5	2.0	0.9	1.8	0.6	2.0	1.0	1.6	0.5
			6	9.7	10.0	1.2	13.8	0.5	2.0	2.2	1.2	2.0	2.3	2.3	1.8	1.9
			8	10.7	7.3	1.1	10.0	0.5	1.3	2.9	1.0	0.6	1.2	4.1	1.0	1.8
	26.40	+8.12	2	7.7	20.2	2.4	27.8	0.5	1.9	0.9	1.5	0.5	2.0	0.8	2.0	0.6
			4	8.7	9.6	1.1	16.1	0.5	1.1	0.8	1.0	1.2	1.3	0.9	1.5	2.4
			6	9.7	6.9	1.1	11.0	0.5	1.0	0.9	1.1	0.6	1.4	2.2	1.3	0.5
			8	10.7	5.6	1.1	8.1	0.5	1.0	5.3	1.0	5.1	1.0	5.4	1.3	5.0
14.0	14.00	-5.48	2	6.7	24.0	2.8	33.3	0.6	1.6	0.9	1.7	2.8	1.9	2.4	1.8	0.6
			4	7.7	12.0	1.3	18.6	0.3	1.3	2.3	1.4	0.6	1.3	1.0	2.0	1.9
			6	8.7	7.3	1.3	12.4	0.6	1.0	0.9	1.2	5.2	1.0	5.6	2.0	5.0
			8	9.7	4.8	1.2	9.8	0.6	1.1	1.0	1.0	0.6	1.5	0.9	1.2	1.9
	19.48	Original	2	6.7	22.0	2.6	28.5	0.6	1.8	1.0	1.3	0.6	1.7	0.9	1.5	0.6
			4	7.7	12.8	1.2	16.2	0.5	1.6	0.9	1.0	0.7	1.6	1.0	1.0	0.6
			6	8.7	8.8	1.2	11.5	0.5	1.1	0.9	1.0	0.6	1.6	0.9	1.0	1.9
			8	9.7	6.3	1.2	9.7	0.3	1.6	3.6	1.0	2.9	2.0	2.3	1.1	3.3
	25.40	+5.92	2	6.7	18.5	2.5	26.0	0.5	1.8	0.9	1.5	0.6	1.9	0.9	2.0	4.6
			4	7.7	8.8	1.2	15.2	0.5	1.1	0.9	1.0	0.6	1.3	1.0	1.1	0.6
			6	8.7	5.8	1.1	10.7	0.5	1.1	6.1	1.0	0.6	1.3	0.9	1.5	5.7
			8	9.7	4.2	1.2	9.5	0.5	1.0	3.3	1.0	1.1	1.0	7.3	1.2	4.5
11.0	14.0	-3.0	2	5.8	20.0	1.3	33.2	0.6	1.0	0.4	1.0	0.6	1.2	1.0	1.4	0.8
			4	6.8	10.1	1.3	18.0	0.6	1.0	0.9	1.2	0.6	1.8	1.0	1.7	2.0
			6	7.8	7.5	1.6	11.8	0.6	1.0	0.9	1.0	0.7	1.2	1.8	1.2	2.0

(Continued)

Table 14 (Continued)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Longitudinal, Upstream, Time min	Longitudinal, Downstream, Pull tons	Longitudinal, Downstream, Time min	Upstream Transverse, Left, Pull tons	Upstream Transverse, Left, Time min	Upstream Transverse, Right, Pull tons	Upstream Transverse, Right, Time min	Downstream Transverse, Left, Pull tons	Downstream Transverse, Left, Time min	Downstream Transverse, Right, Pull tons	Downstream Transverse, Right, Time min
11.0	20.68	Original	2	5.8	22.5	2.7	28.0	0.5	1.1	2.2	1.1	3.4	1.5	3.8	2.0	3.3
			4	6.8	11.0	1.2	15.5	0.5	1.0	1.6	1.1	1.3	1.2	3.7	2.2	3.3
			6	7.8	7.8	1.2	11.1	0.5	1.0	2.9	1.0	0.6	1.0	3.7	1.2	1.9
	24.42	+3.74	2	5.8	17.8	2.6	25.5	0.6	1.6	0.9	1.2	0.6	1.2	1.0	1.8	0.6
			4	6.8	9.2	1.2	14.5	0.5	1.0	1.0	1.0	0.6	1.1	0.9	1.2	0.5
			6	7.8	6.5	1.1	9.9	0.5	1.0	0.9	1.1	0.6	1.1	0.9	1.5	3.4
7.0	15.0	-5.38	2	4.8	14.2	1.7	25.5	0.6	1.2	1.0	1.2	0.7	1.7	1.1	2.2	2.1
			4	5.8	8.5	5.0	14.8	0.6	1.2	1.0	1.0	0.7	1.4	1.0	1.4	2.1
			6	6.8	6.3	1.7	11.1	0.6	1.0	1.1	1.0	0.6	1.0	1.9	1.0	1.4
	20.38	Original	2	4.8	16.0	1.3	22.2	0.6	2.2	2.3	1.3	0.7	1.5	2.4	3.2	2.0
			4	5.8	9.4	1.2	15.0	0.5	1.5	1.6	1.1	0.7	1.2	1.0	2.0	2.0
			6	6.8	6.6	1.2	9.9	0.5	1.0	2.3	1.0	1.3	1.1	1.0	1.0	1.9
	26.20	+5.82	2	4.8	13.0	1.2	20.9	0.5	1.0	1.1	1.5	0.6	1.7	0.9	1.1	0.7
			4	5.8	7.0	1.2	13.0	0.5	1.0	0.9	1.0	0.7	1.1	1.0	1.0	0.6
			6	6.8	4.9	1.2	8.9	0.5	1.0	1.0	1.0	0.6	1.0	0.9	1.0	0.6
5.0	14.0	-6.58	2	4.2	16.8	1.8	22.0	0.6	1.7	1.1	1.3	0.7	2.0	1.0	1.9	0.7
			4	5.2	9.5	1.7	13.8	0.6	1.1	1.1	1.0	0.6	1.4	3.1	1.2	0.7
			6	6.2	5.9	1.7	10.4	0.7	1.0	1.1	1.0	0.6	1.7	0.7	1.0	1.4
	20.58	Original	2	4.2	13.4	1.6	22.0	0.6	1.5	1.6	1.0	1.3	1.9	1.0	1.6	0.9
			4	5.2	6.4	1.2	12.2	0.5	1.2	2.3	1.0	3.3	1.0	0.9	1.0	2.0
			6	6.2	5.0	1.2	9.5	0.5	1.4	2.9	1.0	2.7	1.0	3.1	1.0	3.3
	26.4	+5.82	2	4.2	11.5	2.7	17.5	0.5	1.5	0.9	1.0	0.6	1.3	0.9	1.4	0.5
			4	5.2	5.9	1.2	10.5	0.6	1.1	1.1	1.0	0.6	1.2	1.0	1.2	2.0
			6	6.2	4.1	1.2	7.5	0.5	1.1	1.0	1.0	1.2	1.1	0.9	1.4	0.7
3.0	14.00	-4.78	1	2.8	26.3	1.8	27.8	0.6	1.7	1.2	1.5	0.6	2.2	1.0	1.6	0.8
			2	3.3	15.5	1.8	17.8	0.6	1.1	1.6	1.1	0.6	1.1	1.1	1.2	0.8
			4	4.3	6.7	1.7	11.3	0.6	1.0	1.1	1.0	0.6	1.0	2.0	1.2	0.8

(Continued)

Table 14 (Concluded)

Initial Lift ft	Clearance Between Ship and Chamber Floor, ft	Relation to Original Clearance ± ft	Valve Time min	Emptying Time min	Maximum Hawser Forces: Longitudinal, Upstream, Pull tons	Longitudinal, Upstream, Time min	Longitudinal, Downstream, Pull tons	Longitudinal, Downstream, Time min	Upstream Transverse, Left, Pull tons	Upstream Transverse, Left, Time min	Upstream Transverse, Right, Pull tons	Upstream Transverse, Right, Time min	Downstream Transverse, Left, Pull tons	Downstream Transverse, Left, Time min	Downstream Transverse, Right, Pull tons	Downstream Transverse, Right, Time min
3.0	19.78	Original	1	2.8	23.0	1.6	24.0	0.6	2.0	1.7	1.0	1.9	1.8	1.8	1.8	2.0
			2	3.3	12.0	1.6	16.0	0.7	1.6	1.0	1.0	2.0	1.1	0.6	1.0	0.4
			4	4.3	6.8	1.6	10.0	0.5	1.0	1.1	1.0	4.1	1.3	3.8	1.0	0.7
	26.2	+6.42	1	2.8	16.5	1.3	20.0	0.6	1.1	1.1	1.0	0.6	1.7	1.0	1.6	2.1
			2	3.3	9.3	1.3	13.5	0.5	1.3	1.0	1.1	0.6	2.0	1.0	1.9	0.6
			4	4.3	4.7	1.2	8.3	0.5	1.0	0.8	1.0	0.6	1.0	0.9	1.0	1.1
2.0	14.00	-5.98	1	2.2	22.6	1.8	22.0	0.6	1.5	1.1	1.0	2.3	1.2	1.8	1.5	1.5
			2	2.7	14.5	1.8	15.0	0.7	1.4	1.9	1.0	2.2	1.3	1.8	1.3	2.3
			4	3.7	6.6	1.8	9.2	0.6	1.0	2.0	1.0	2.2	1.4	1.8	1.0	2.4
	19.98	Original	1	2.2	18.0	1.7	20.2	0.6	2.0	1.0	1.0	1.5	1.0	1.2	2.0	0.7
			2	2.7	9.9	1.7	13.2	0.6	1.2	1.8	1.0	2.0	1.0	1.0	1.1	2.1
			4	3.7	5.0	1.6	8.4	0.6	1.0	1.1	1.0	2.1	1.0	0.9	1.0	0.7
	25.40	+5.42	1	2.2	13.5	1.2	18.0	0.6	1.0	0.9	1.2	0.6	1.9	1.0	1.3	0.6
			2	2.7	6.0	1.2	11.8	0.6	1.0	1.0	1.0	0.6	1.0	1.0	1.1	2.0.
			4	3.7	3.5	1.2	7.3	0.5	1.0	1.1	1.0	1.4	1.0	0.9	1.0	0.7
1.0	15.0	-5.18	1	1.6	14.6	1.8	14.5	0.6	1.0	0.6	1.0	0.7	1.0	1.0	1.2	0.8
			2	2.1	9.5	1.8	10.2	0.6	1.0	1.2	1.0	0.7	1.0	1.1	1.0	0.8
			4	3.1	4.7	1.8	6.3	1.0	1.0	0.8	1.0	0.6	1.0	1.7	1.0	0.8
	20.18	Original	1	1.6	11.6	1.7	12.1	0.6	1.0	1.1	1.0	1.3	1.0	1.0	1.0	2.1
			2	2.1	7.3	1.7	10.3	0.6	1.0	1.9	1.0	2.1	1.0	1.0	1.0	1.5
			4	3.1	4.4	3.0	6.3	0.6	1.0	2.9	1.0	1.3	1.0	1.0	1.0	2.4
	25.40	+5.22	1	1.6	9.0	1.3	11.9	0.6	1.0	1.2	1.3	0.7	1.3	1.0	1.2	0.8
			2	2.1	6.9	2.8	9.5	0.6	1.0	1.7	1.0	1.3	1.0	1.7	1.0	0.7
			4	3.1	3.2	3.0	6.3	0.6	1.0	1.6	1.0	1.3	1.0	1.0	1.0	0.7

(Sheet 3 of 3)

Table 15

Type 15 Sidewall Port Manifold System, Valve Time, Min, Required to Limit Hawser Forces on Ship with Minimum Stage Conditions and Clearances Plus 5- and/or 10-ft Additional Clearance

Ship Draft and Displacement	Minimum Stage Clearance Plus 5- and 10-ft Additional Clearance	Hawser Force Limit tons	Filling and Emptying Valve Time, Min, Required to Limit Hawser Forces as Indicated for Lift Differentials, ft															
			1		2		3		5		7		11		14		18.4	
			F_v	E_v	F_v	E_v	F_v	E_v	F_v	E_v	F_v	E_v	F_v	E_v	F_v	E_v	F_v	E_v
45 ft	Min Stage	25	2	2	3	3	5	4	5	5	5	5	7	6	9	6	12	7
171,000 tons	Min Stage + 5-ft	25	1	1	2	2	4	3	4	4	4	5	5	5	7	5	8	6
	Min Stage + 10-ft	25	1	1	2	2	3	2	3	4	3	4	4	4	5	5	6	5
	Min Stage	20	3	3	4	5	5	6	5	6	8	7	9	8	12	8	16	8
	Min Stage + 5-ft	20	2	2	3	3	4	4	4	5	6	6	6	7	9	7	10	8
	Min Stage + 10-ft	20	1	1	2	2	3	3	4	5	4	5	5	6	7	6	8	7
37.5 ft	Min Stage	25	1	1	2	2	3	3	3	3	3	4	4	4	4	5	6	5
142,000 tons	Min Stage + 5-ft	25	1	1	1	1	2	2	2	3	3	3	3	4	3	4	4	4
	Min Stage + 10-ft	25	1	1	1	1	2	2	2	2	2	3	3	3	3	4	4	4
	Min Stage	20	2	2	3	3	3	4	4	4	4	5	6	5	7	6	8	7
	Min Stage + 5-ft	20	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	5
	Min Stage +10-ft	20	1	1	1	2	2	2	3	3	3	4	4	4	4	4	5	5
30 ft	Min Stage	20	--	--	1	2	2	2	2	2	2	3	3	3	3	3	4	4
114,000 tons	Min Stage + 5-ft	20	--	--	1	1	1	1	2	2	2	2	3	3	3	3	3	4
	Min Stage	10	1	2	2	3	3	4	4	5	5	6	6	7	7	7	9	8
	Min Stage + 5-ft	10	1	2	2	3	3	3	4	5	4	6	5	6	6	7	7	8

Note: Clearance is the distance in feet between the bottom of the ship and floor of the lock chamber. ing valve and emptying valve are indicated respectively, F_v and E_v.

PHOTOGRAPHS

a. 2 min after filling started

b. 5 min after filling started

Photo 1. Surface currents during filling operation at original design intake manifolds (10-sec exposure) with 2-min valve schedule. Initial lift 18.4 ft (upper pool el +15.9, lower pool el -2.5)

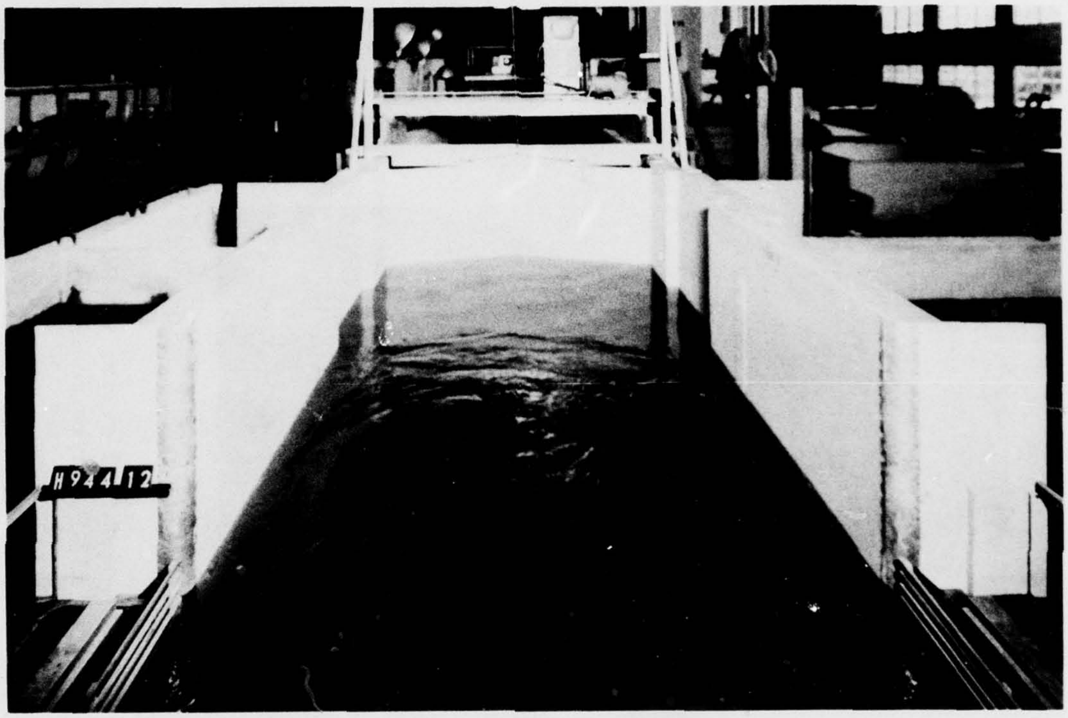
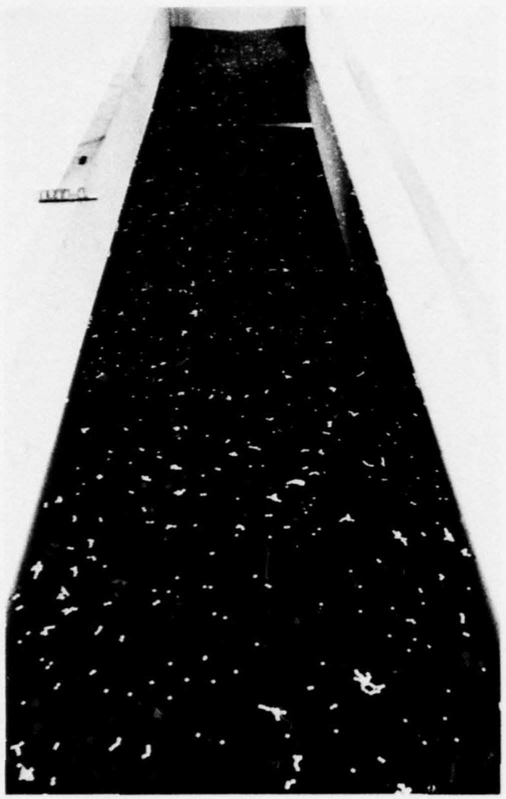
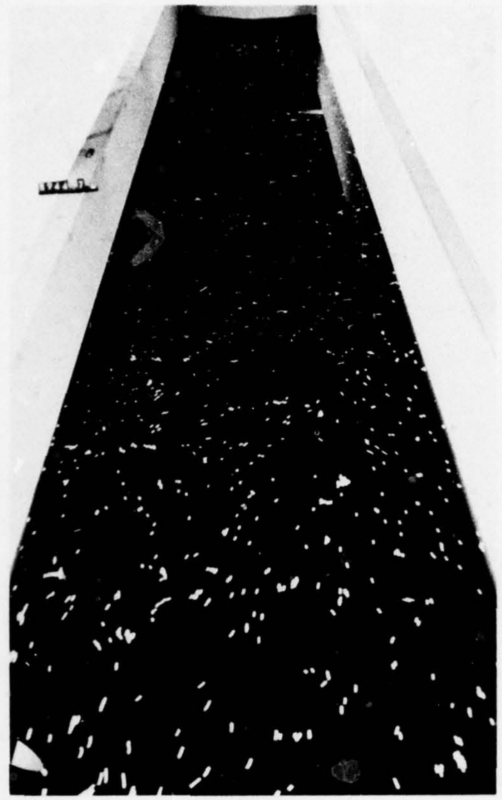


Photo 2. Turbulence over original design outlet manifold at maximum discharge condition 2 min after emptying started with 2-min valve schedule. Initial lift 18.4 ft (lock chamber el +15.9, lower pool el -2.5)



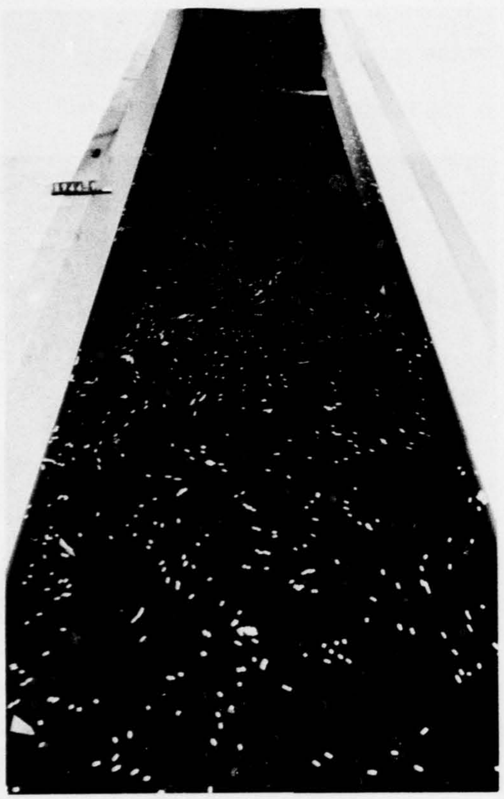
a. Before filling started



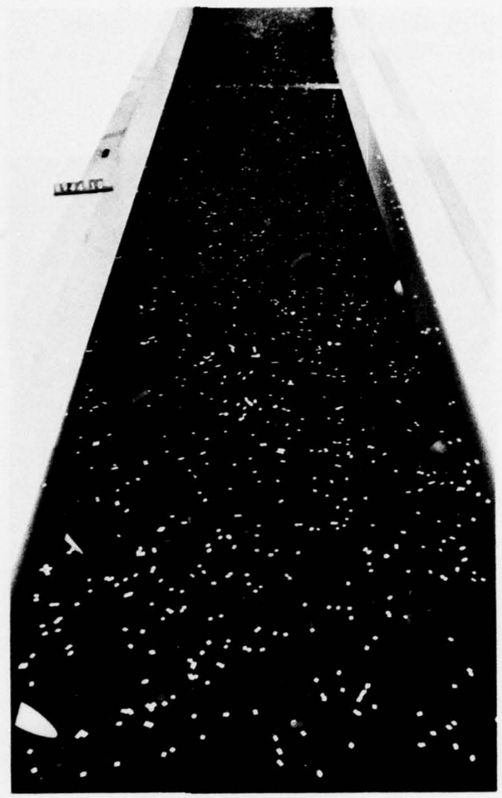
b. 2 min after filling started

c. 3.5 min after filling started

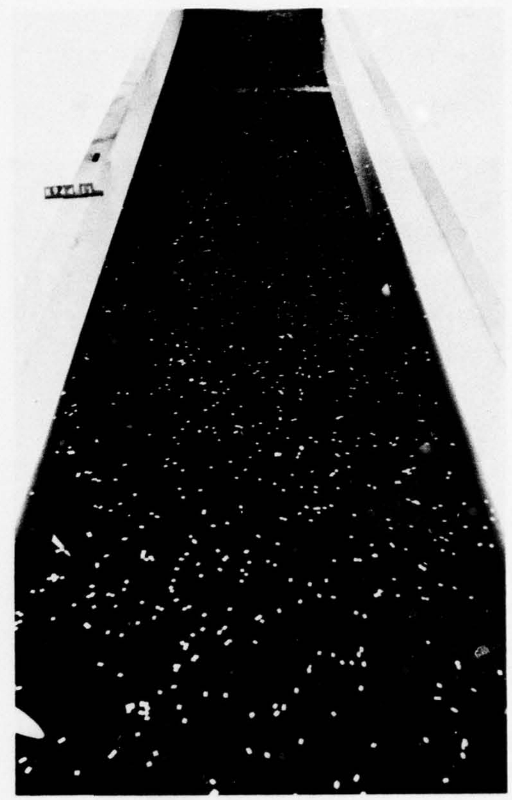
Photo 3. Original design sidewall port manifold system with 2-min valve schedule. Initial lift 18.4 ft (upper pool el +15.9, lower pool el -2.5) (sheet 1 of 2)



d. 5.0 min after filling started

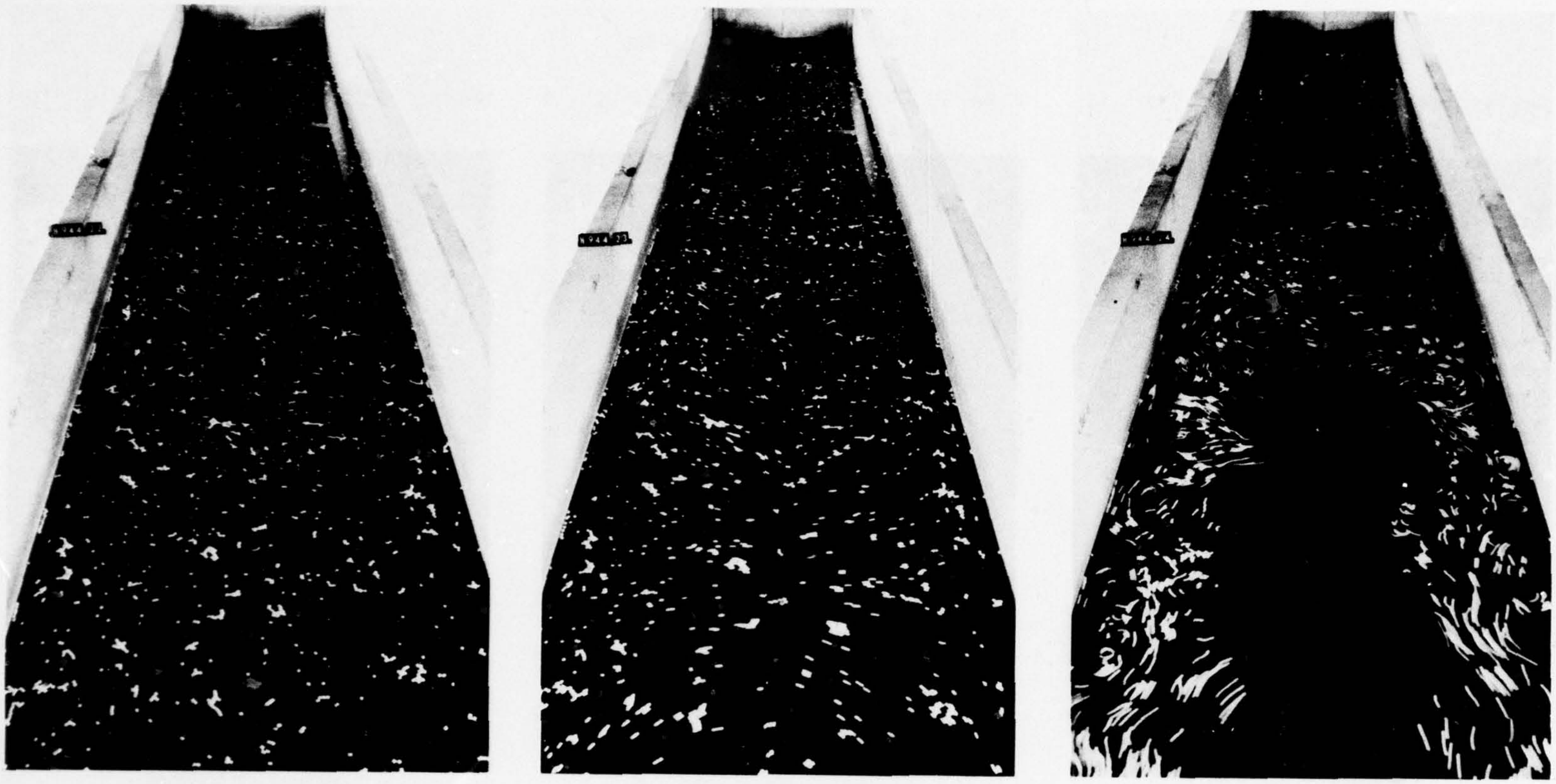


e. 6.25 min after filling started



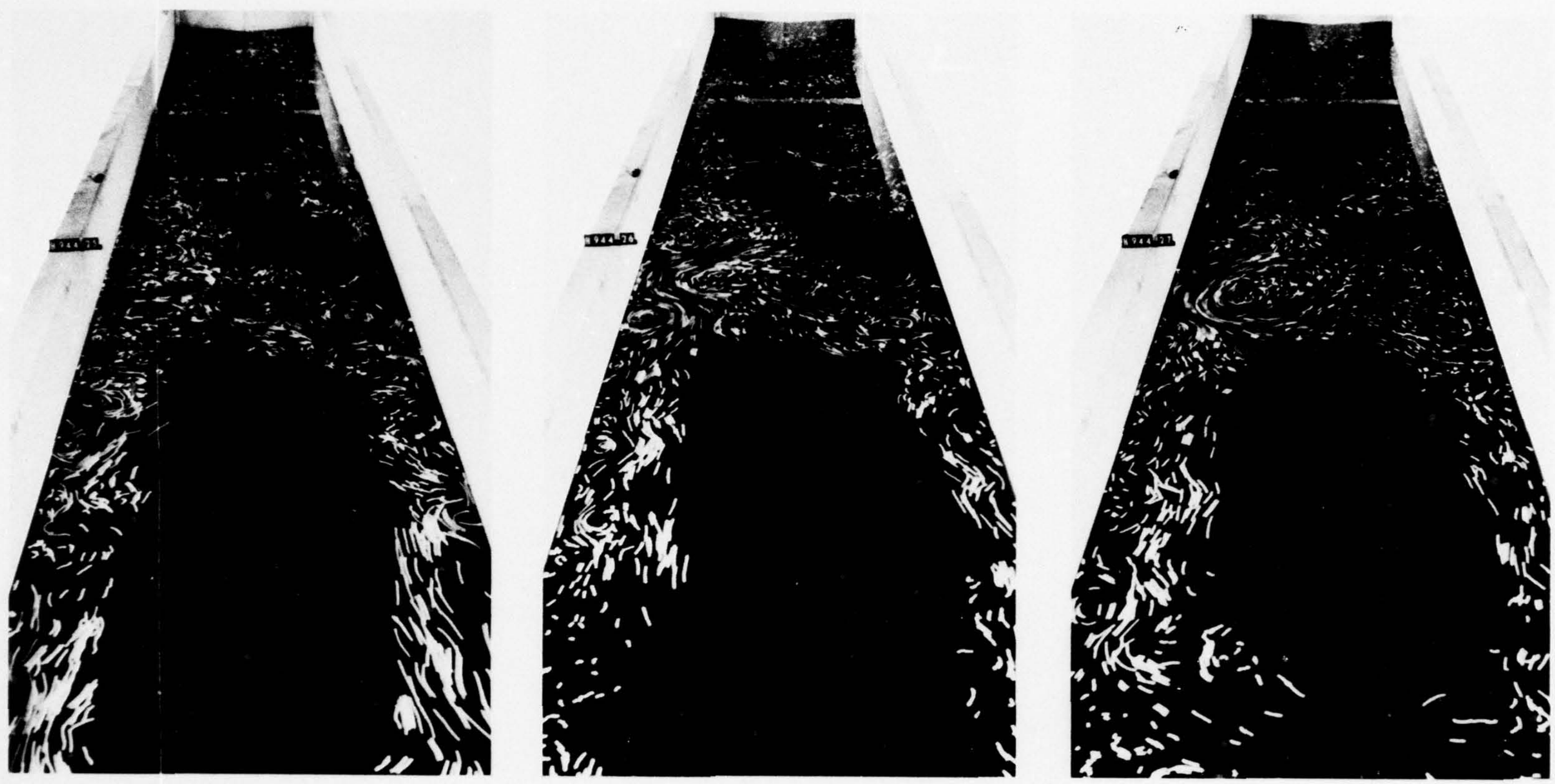
f. 7.5 min after filling started

Photo 3 (sheet 2 of 2)



a. Before filling started b. 2 min after filling started c. 4 min after filling started

Photo 4. Type 15 port arrangement with 4-min valve schedule. Initial lift 18.4 ft (upper pool el +15.9, lower pool el -2.5) (sheet 1 of 2)

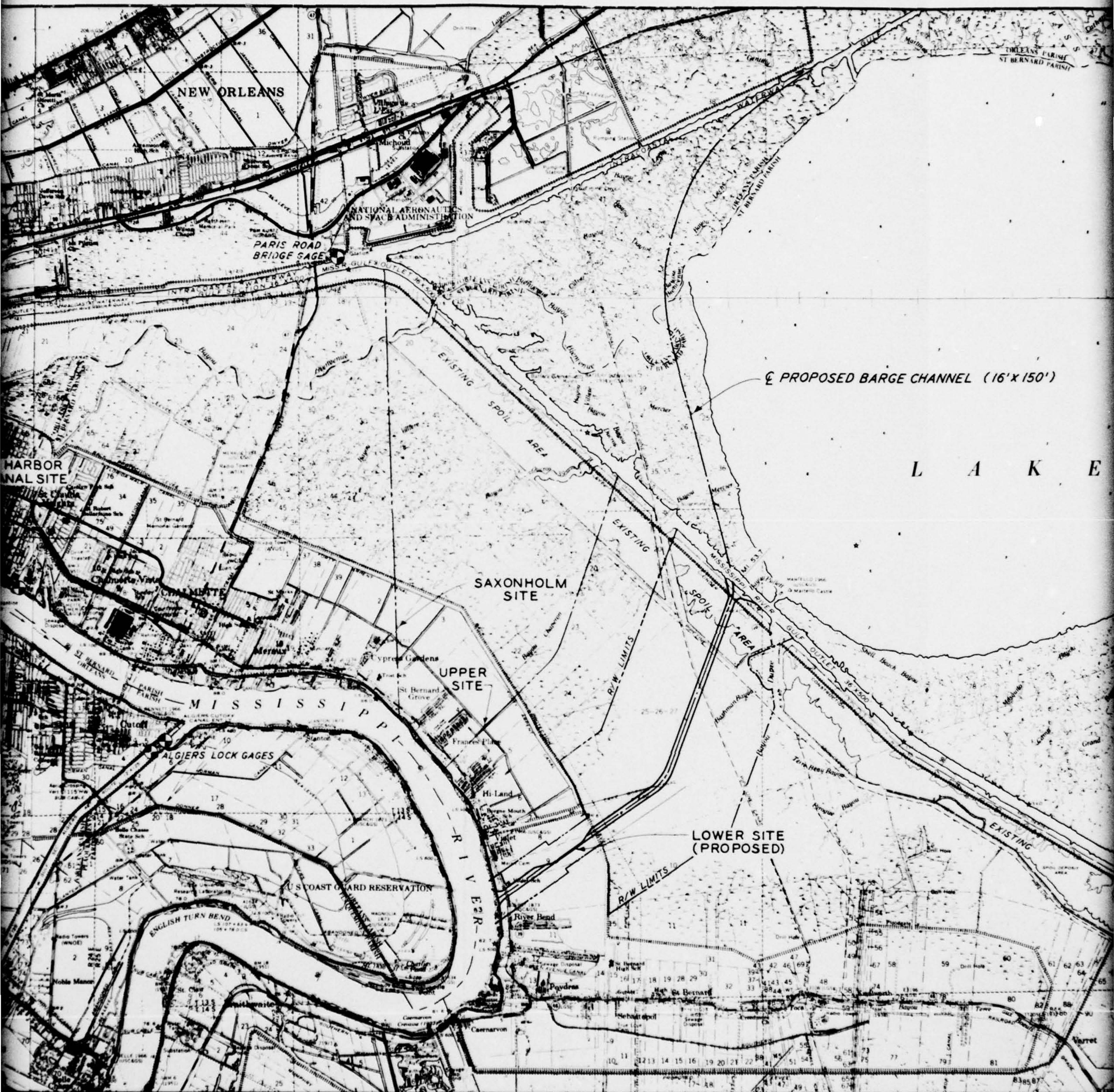


d. 5.3 min after filling started   e. 7.0 min after filling started   f. 9.0 min after filling started

Photo 4 (sheet 2 of 2)


LAKE PONTCHARTRAIN
SEABROOK LOCK AND DIKE (PROPOSED)
SEABROOK BRIDGE GAGE
NEW ORLEANS LAKEFRONT AIRPORT
WEST END GAGE
West End
Indian Beach
Pontchartrain Beach
FLORIDA AVE BRIDGE GAGE
INNER HARBOR NAV. CANAL LOCK GAGES
INNER HARBOR NAV. CANAL SITE
CHALMETTE, LA GAGE - MI 91.0
CARROLLTON, LA GAGE - MI 102.8
HARVEY LOCK GAGES
CARROLLTON BEND
GREENVILLE BEND
LOCATION MAP
SCALE

1



NEW ORLEANS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PARIS ROAD BRIDGE GAGE
HARBOR
ANAL SITE
CHALMETTE
SAXONHOLM SITE
UPPER SITE
Cypress Gardens
St Bernard Grove
MISSISSIPPI RIVER
ALGIERS LOCK GAGES
Hi-Land
U S COAST GUARD RESERVATION
ENGLISH TURN BEND
River Bend
Poydras
St Bernard
Caernarvon
Verret
EXISTING SPOIL AREA
R/W LIMITS
LOWER SITE (PROPOSED)
℄ PROPOSED BARGE CHANNEL (16' x 150')
MISSISSIPPI RIVER GULF OUTLET
INTRACOASTAL WATERWAY
ORLEANS PARISH
ST BERNARD PARISH
L A K E
EXISTING

2

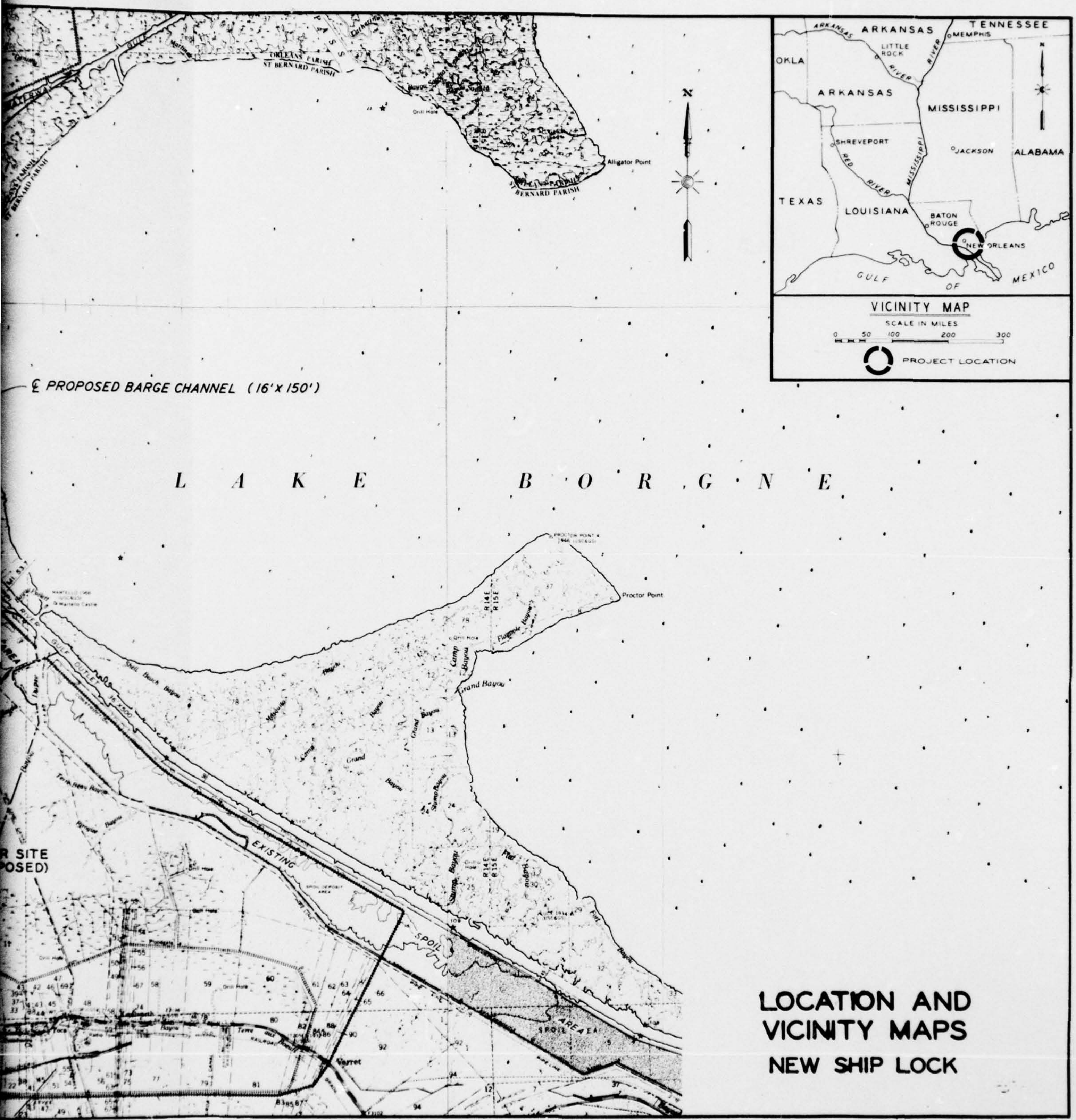
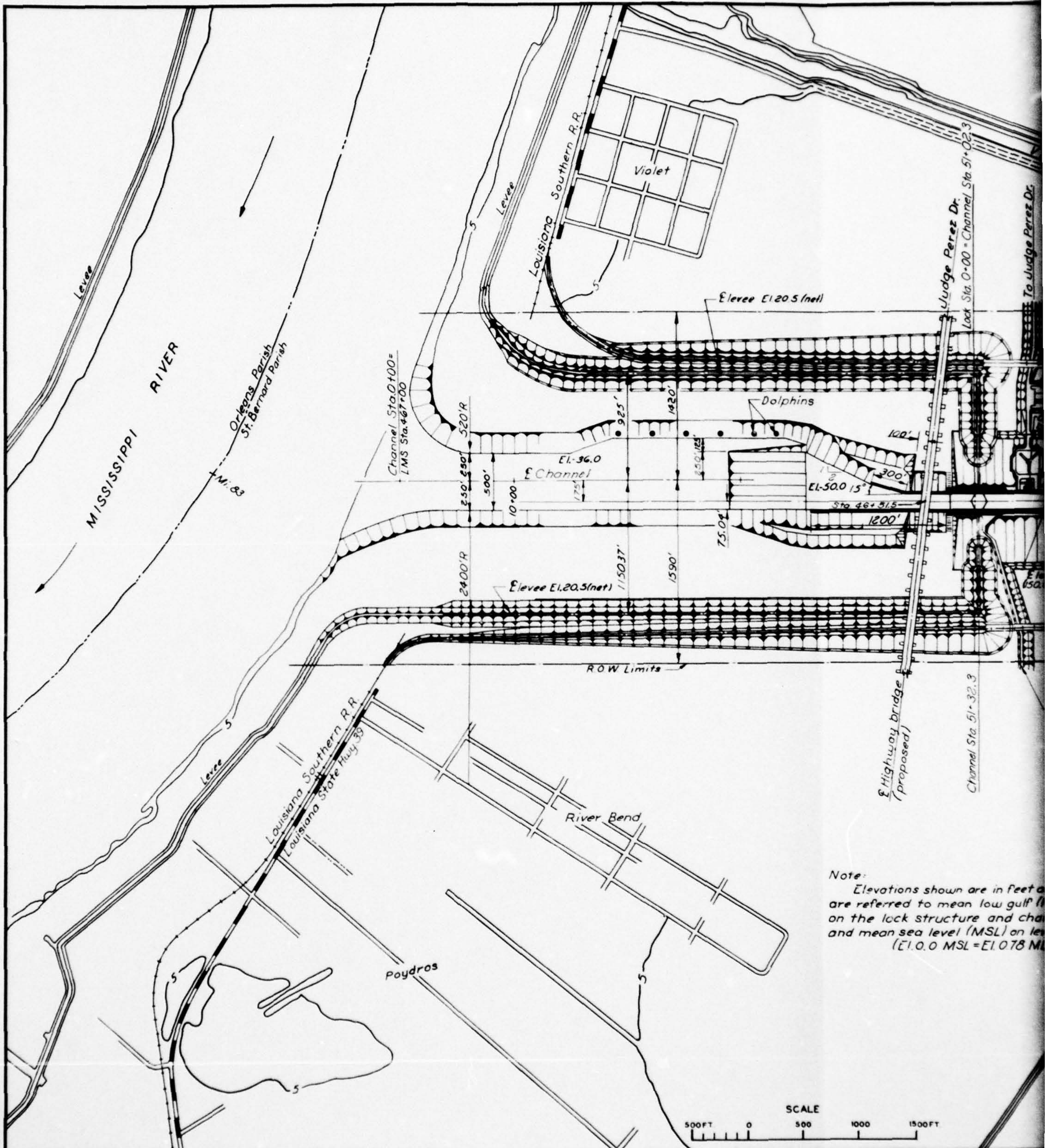

ARKANSAS
TENNESSEE
MEMPHIS
LITTLE ROCK
OKLA
ARKANSAS
MISSISSIPPI
SHREVEPORT
JACKSON
ALABAMA
TEXAS
LOUISIANA
BATON ROUGE
NEW ORLEANS
GULF OF MEXICO
VICINITY MAP
SCALE IN MILES
0 50 100 200 300
PROJECT LOCATION
ORLEANS PARISH
ST BERNARD PARISH
Drill Hole
Alligator Point
N
℄ PROPOSED BARGE CHANNEL (16'x 150')
L A K E B O R G N E
Proctor Point
Grand Bayou
Camp Bayou
EXISTING
SPOIL
SPOIL AREA
Verret
R SITE
POSED)
LOCATION AND
VICINITY MAPS
NEW SHIP LOCK

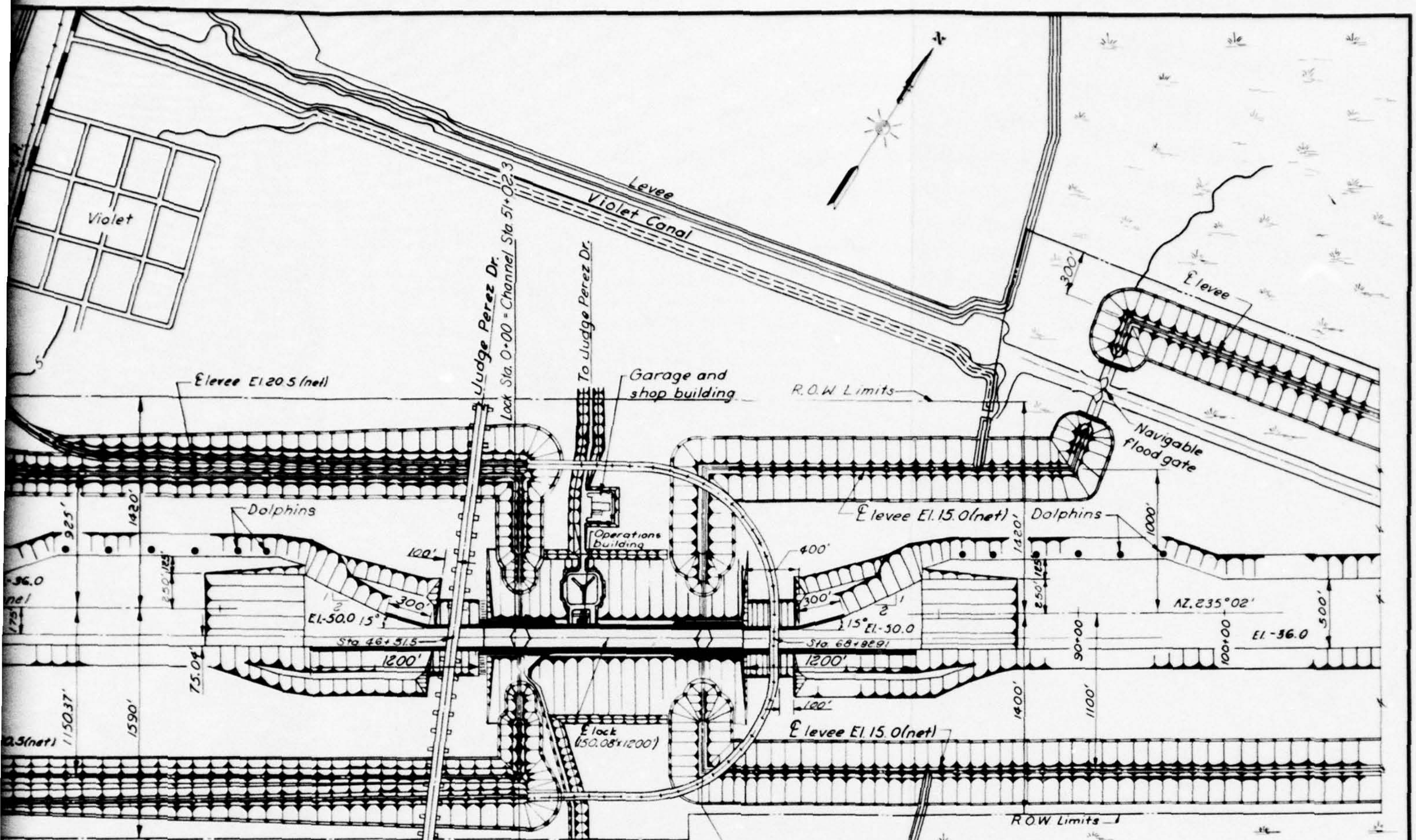
PLATE 1

3



Levee
MISSISSIPPI RIVER
Orleans Parish
St. Bernard Parish
Mi. 83
Louisiana Southern R.R.
Violet
Levee
5
Judge Perez Dr.
Lock Sta. 0+00 = Channel Sta. 51+02.3
To Judge Perez Dr.
℄ levee El. 20.5 (net)
Channel Sta. 0+00 = LMS Sta. 467+00
520'R
925'
1420'
Dolphins
100'
El. -36.0
℄ Channel
250'
500'
175'
10+00
250'/125'
300'
El. -50.0
15°
Sta. 46+51.5
1200'
75.04'
2400'R
1150.37'
1590'
℄ levee El. 20.5 (net)
ROW Limits
Louisiana Southern R.R.
Louisiana State Hwy. 39
Levee
℄ Highway bridge (proposed)
Channel Sta. 51+32.3
River Bend
Poydras
Note:
Elevations shown are in feet a
are referred to mean low gulf (
on the lock structure and cha
and mean sea level (MSL) on le
(El. 0.0 MSL = El. 0.78 ML
SCALE
500 FT 0 500 1000 1500 FT

1



GENERAL PLAN

NEW SHIP LOCK

PLATE 2

2

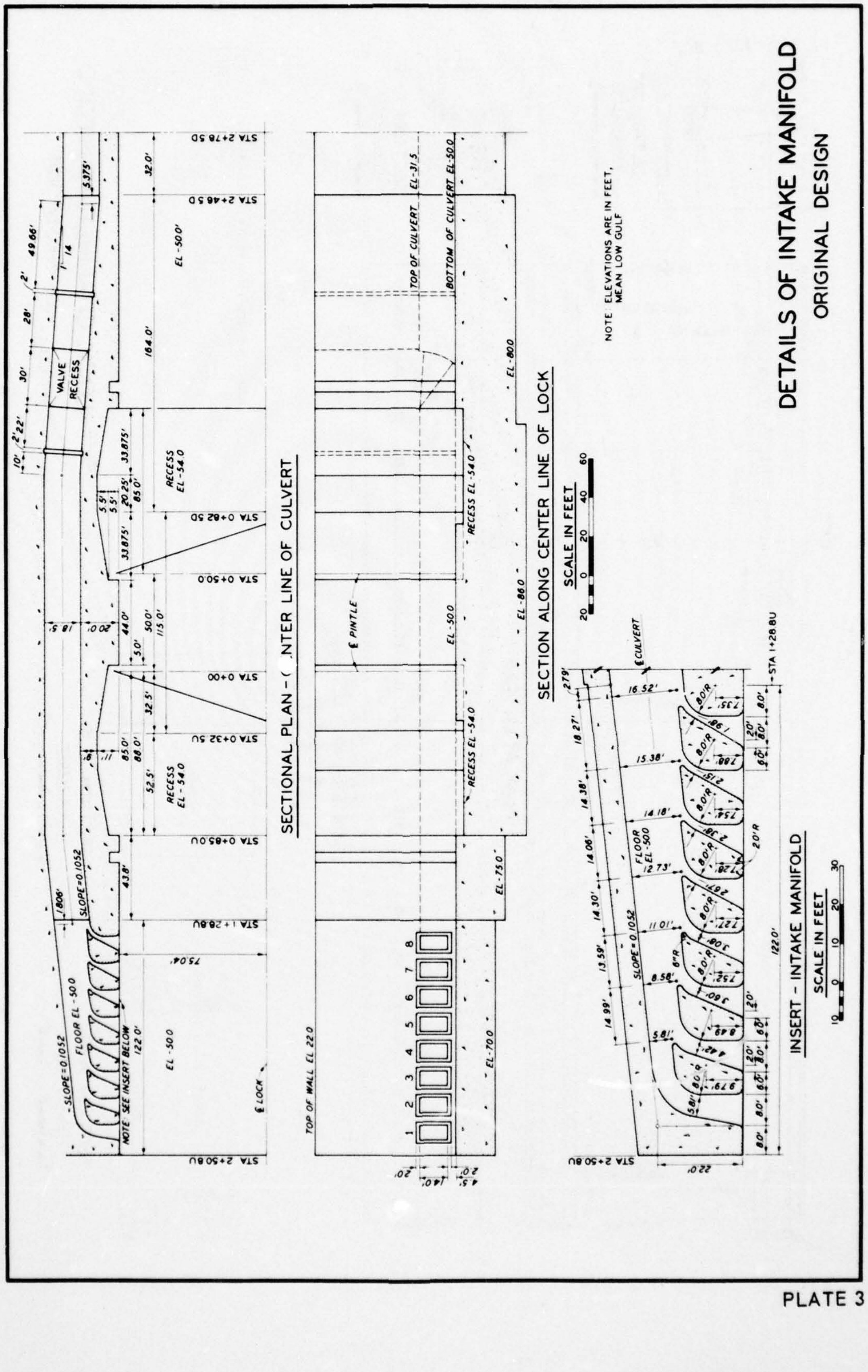

DETAILS OF INTAKE MANIFOLD
ORIGINAL DESIGN
SECTIONAL PLAN - C NTER LINE OF CULVERT
SECTION ALONG CENTER LINE OF LOCK
SCALE IN FEET
INSERT - INTAKE MANIFOLD
SCALE IN FEET
NOTE: ELEVATIONS ARE IN FEET, MEAN LOW GULF
VALVE RECESS
RECESS EL -54.0
TOP OF CULVERT EL -31.5
BOTTOM OF CULVERT EL -50.0
TOP OF WALL EL 22.0
FLOOR EL -50.0
SLOPE = 0.1052
NOTE: SEE INSERT BELOW
℄ LOCK
℄ PINTLE
℄ CULVERT
STA 2+50.8U
STA 1+28.8U
STA 0+85.0U
STA 0+32.5U
STA 0+00
STA 0+50.0
STA 0+82.5D
STA 2+48.5D
STA 2+78.5D

PLATE 3

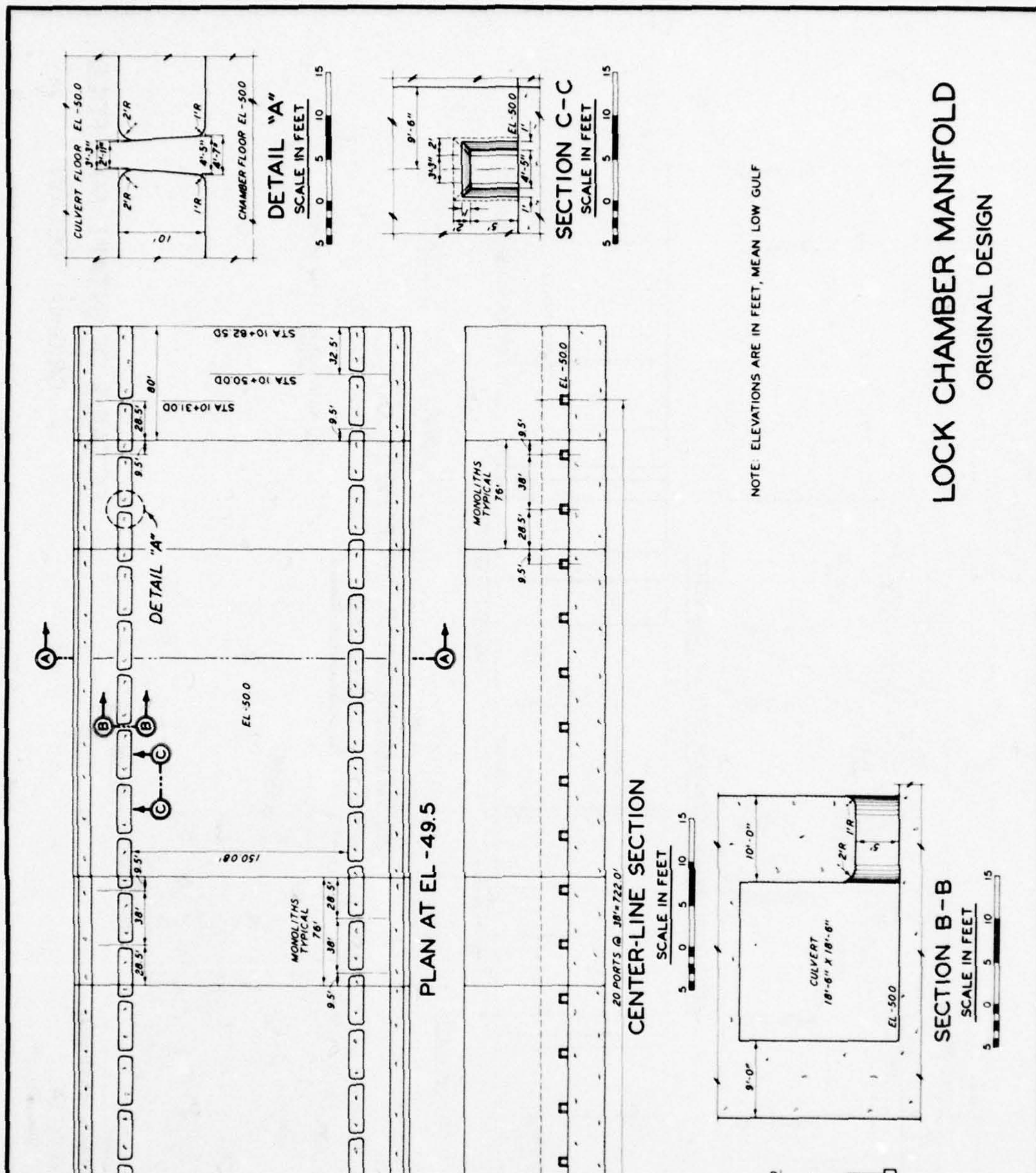
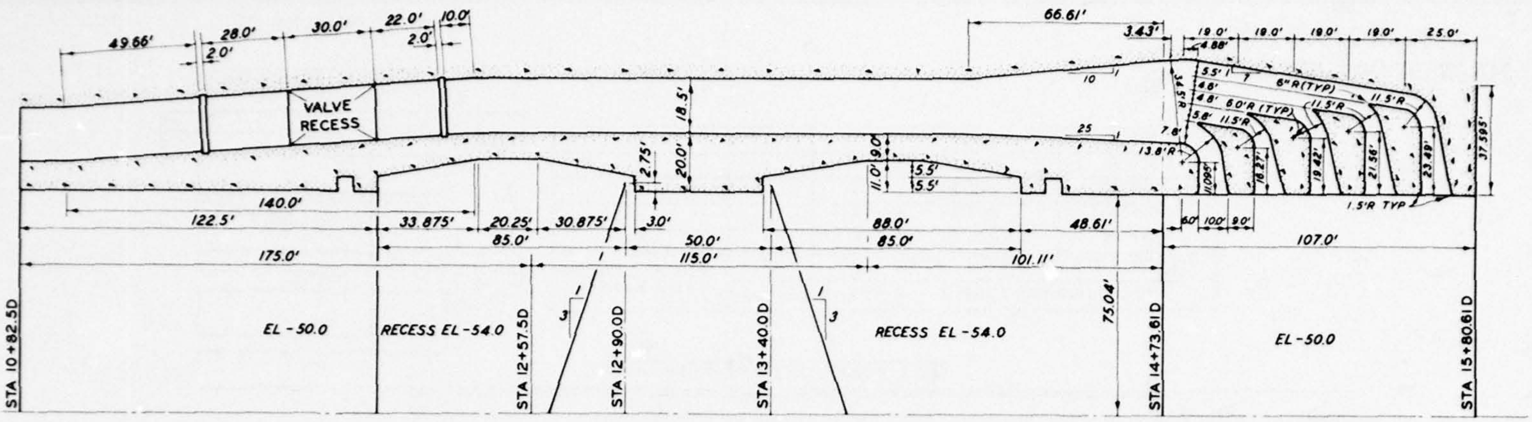
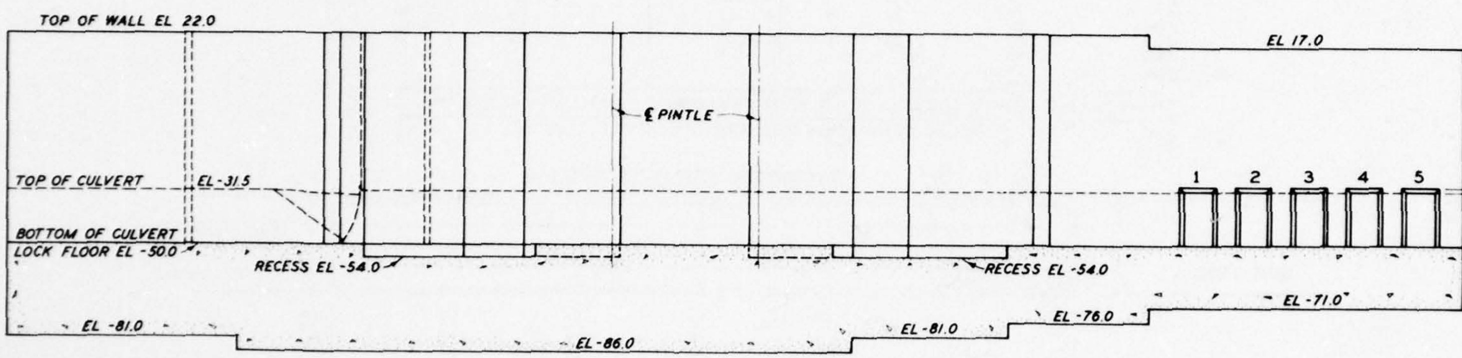

LOCK CHAMBER MANIFOLD
ORIGINAL DESIGN
NOTE: ELEVATIONS ARE IN FEET, MEAN LOW GULF
PLAN AT EL -49.5
DETAIL "A"
EL -50.0
MONOLITHS TYPICAL 76'
STA 10+82.5D
STA 10+50.0D
STA 10+31.0D
STA 3+09.0D
STA 3+18.5D
STA 3+28.0D
STA 2+78.5D
MATCH LINE
150.08'
TOP OF WALL EL 22.0
TOP OF CULVERT EL -31.5
20 PORTS @ 38'=722.0'
CENTER-LINE SECTION
SCALE IN FEET
DETAIL "A"
SCALE IN FEET
CULVERT FLOOR EL -50.0
CHAMBER FLOOR EL -50.0
SECTION C-C
SCALE IN FEET
SECTION B-B
SCALE IN FEET
CULVERT 18'-6" X 18'-6"
SECTION A-A
SCALE IN FEET
BACKFILL
EL 5.0
EL 22.0

PLATE 4



SECTIONAL PLAN-CENTER LINE OF CULVERT



SECTION ALONG CENTER LINE OF LOCK

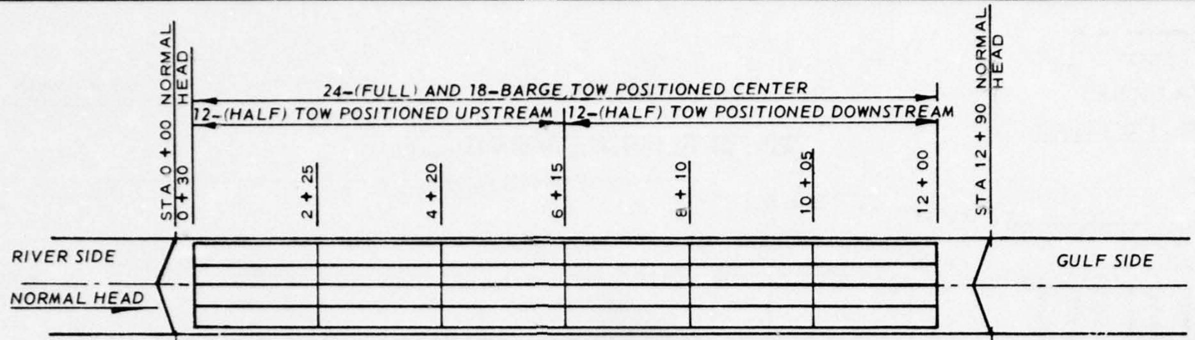
NOTE: ELEVATIONS ARE IN FEET, MEAN LOW GULF

OUTLET MANIFOLD

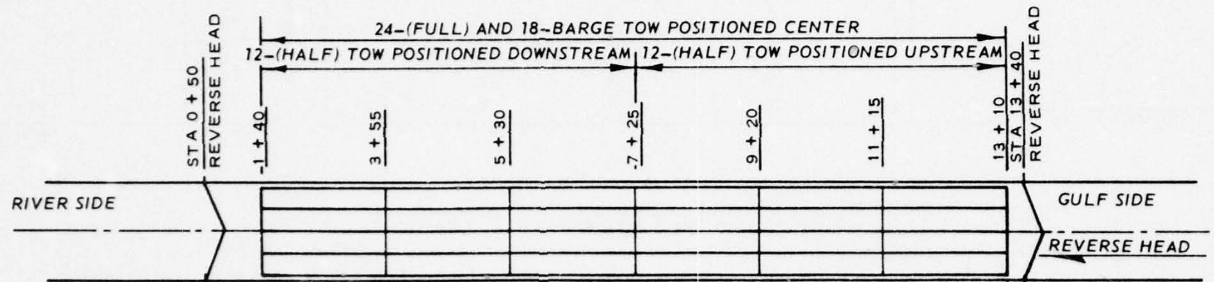
ORIGINAL DESIGN

SCALE IN FEET

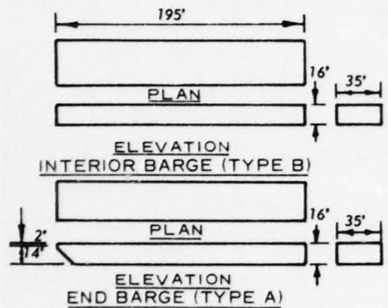
20 0 20 40 60



NORMAL HEAD AND BARGE TOWS



REVERSE HEAD AND BARGE TOWS



BARGE DETAILS

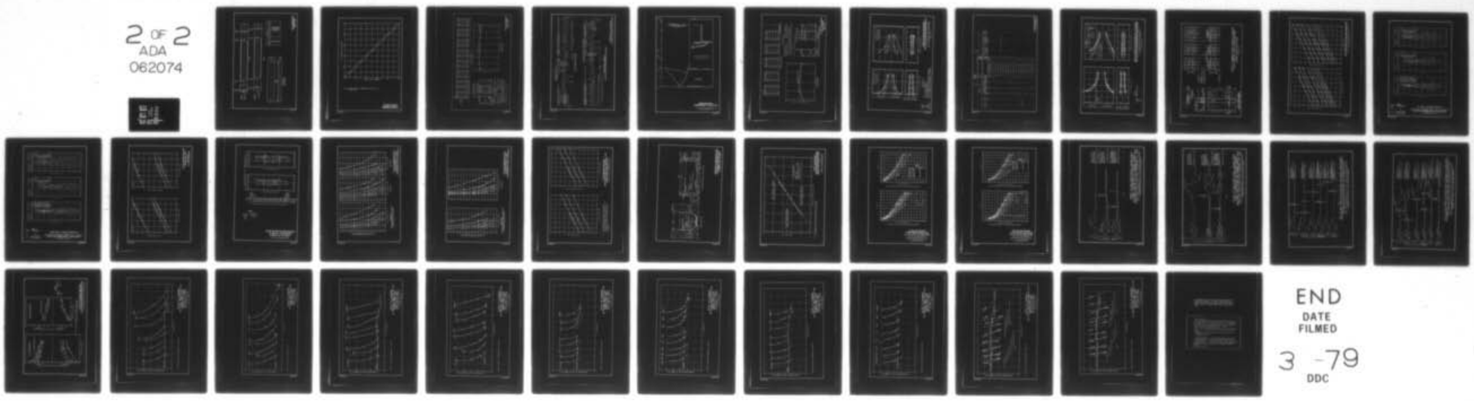
NUMBER OF BARGES IN TOW	BARGE TYPES		DISPLACEMENT, TONS	
	A	B	9-FT DRAFT	12-FT DRAFT
12	4	8	22,120	30,240
18	6	12	33,930	45,360
24	8	16	44,240	60,480
1	1		1,823	2,555
1		1	1,916	2,450

BARGE TOW ARRANGEMENTS AND BARGE DETAILS

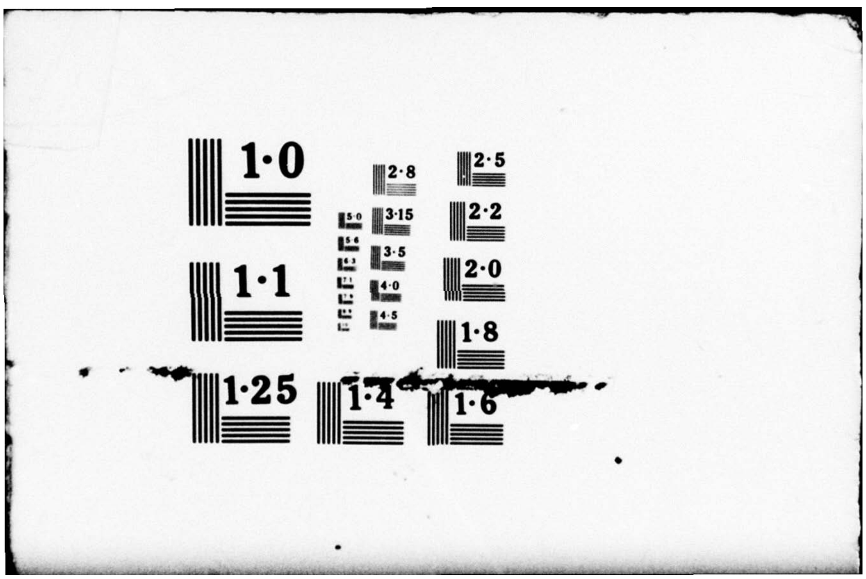
PLATE 6

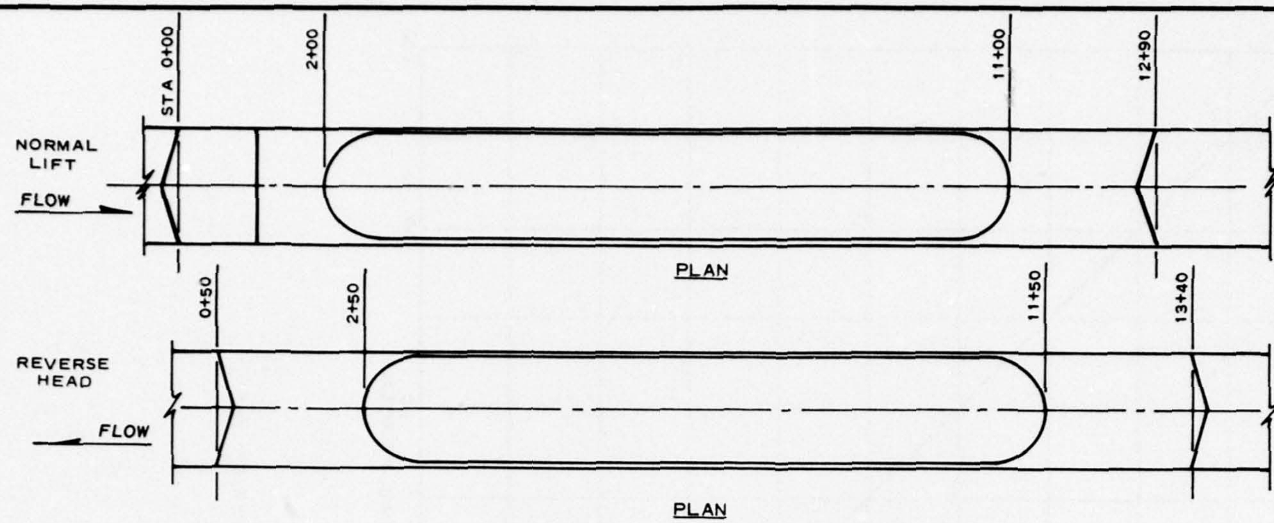
AD-A062 074 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/13
FILLING AND EMPTYING SYSTEM, NEW SHIP LOCK, MISSISSIPPI RIVER-G--ETC(U)
SEP 78 J H ABLES
UNCLASSIFIED WES-TR-H-78-16 NL

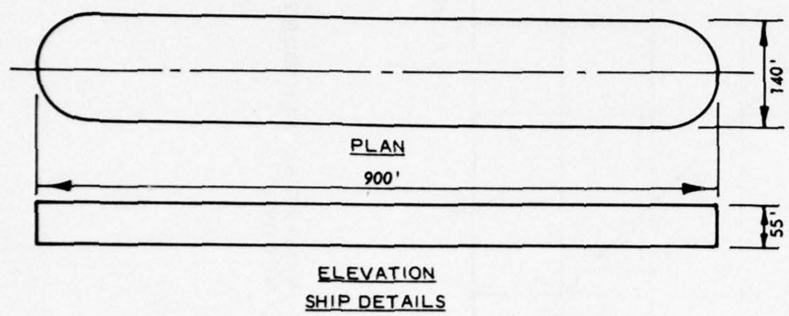
2 OF 2
ADA
062074



END
DATE
FILMED
3-79
DDC

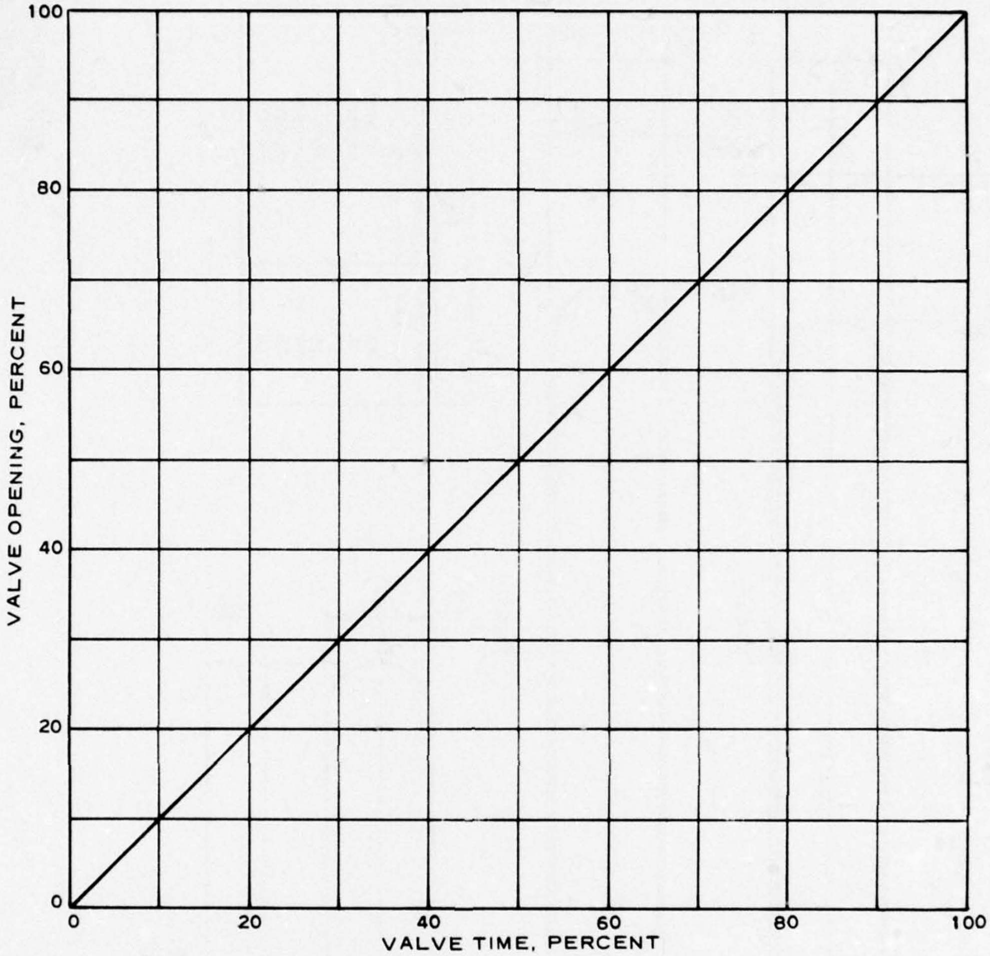

1·0
2·8
2·5
5·0
3·15
2·2
5·6
3·5
2·0
4·0
1·1
4·5
1·8
1·25
1·4
1·6





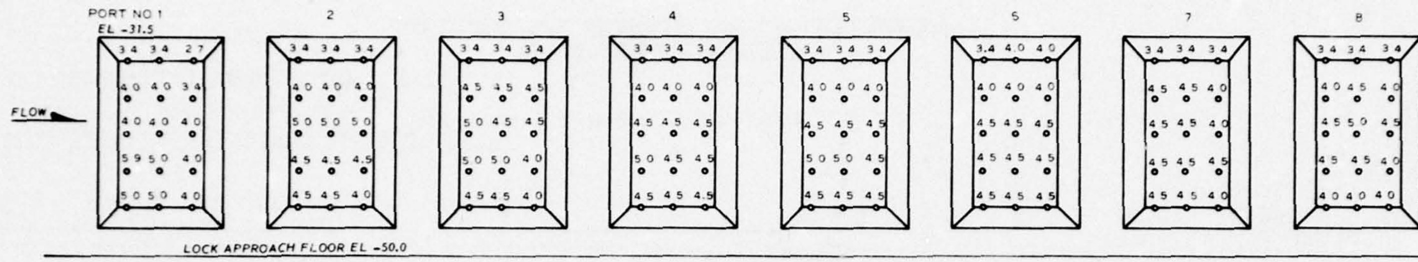
SHIP	
DRAFT, FT	DISPLACEMENT, TONS
45	171,000
40	152,000
37.5	142,500
35	133,000
30	114,000
23	95,000
20	76,000

SHIP ARRANGEMENTS AND DETAILS

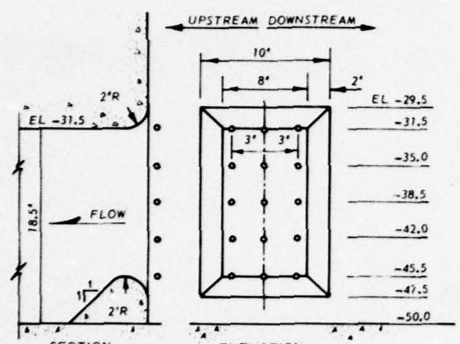


NOTE: FURNISHED BY VICKSBURG DISTRICT, CE.
21 MAY 1973

CULVERT VALVE OPENING SCHEDULE



VELOCITY DISTRIBUTION



SECTION

ELEVATION

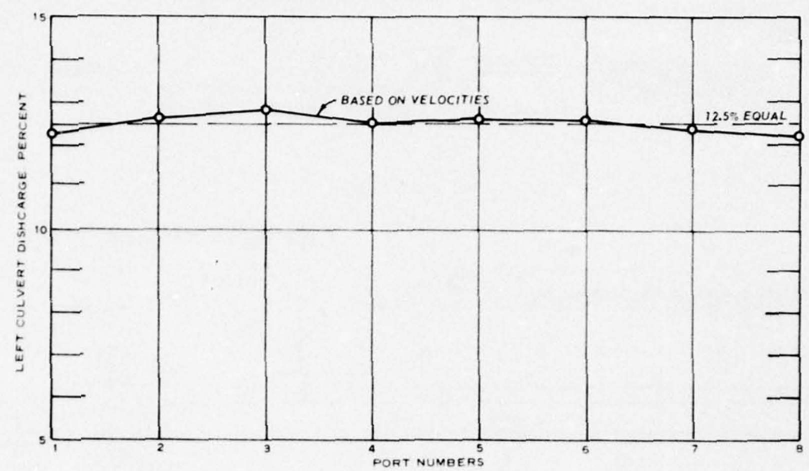
LOCATION OF INTAKE MANIFOLD VELOCITY MEASUREMENTS

TEST CONDITIONS

UPPER POOL EL +15.9	UPPER VALVES FULLY OPEN
LOCK CHAMBER EL +3.6	LOWER VALVES CLOSED
UPPER MITER GATE CLOSED	LOWER MITER GATES OPEN

THIS CONDITION SIMULATES MAXIMUM DISCHARGE ±16,000 CFS DURING A 1-MIN VALVE SCHEDULE FILLING OPERATION WITH INITIAL UPPER POOL +15.9 AND LOWER POOL -2.5 (18.4 FT LIFT)

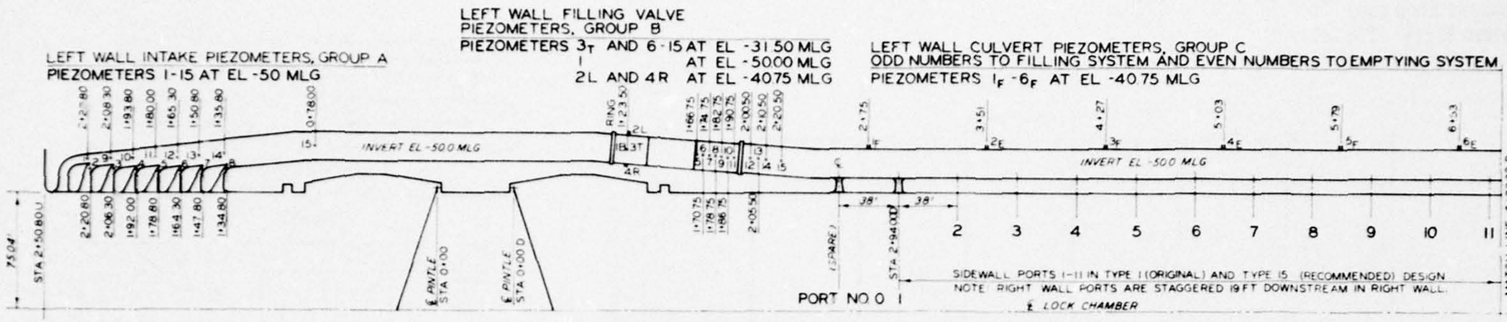
NOTE VELOCITIES ARE IN FEET PER SECOND.



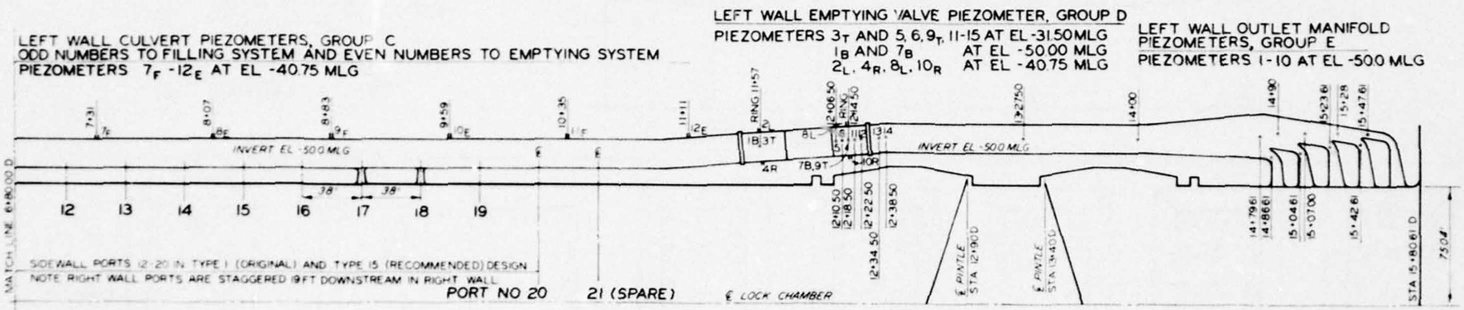
FLOW DISTRIBUTION

LEFT WALL INTAKE MANIFOLD FLOW DISTRIBUTION

ORIGINAL DESIGN



STA 2+50.80 U – 6+80.00 D

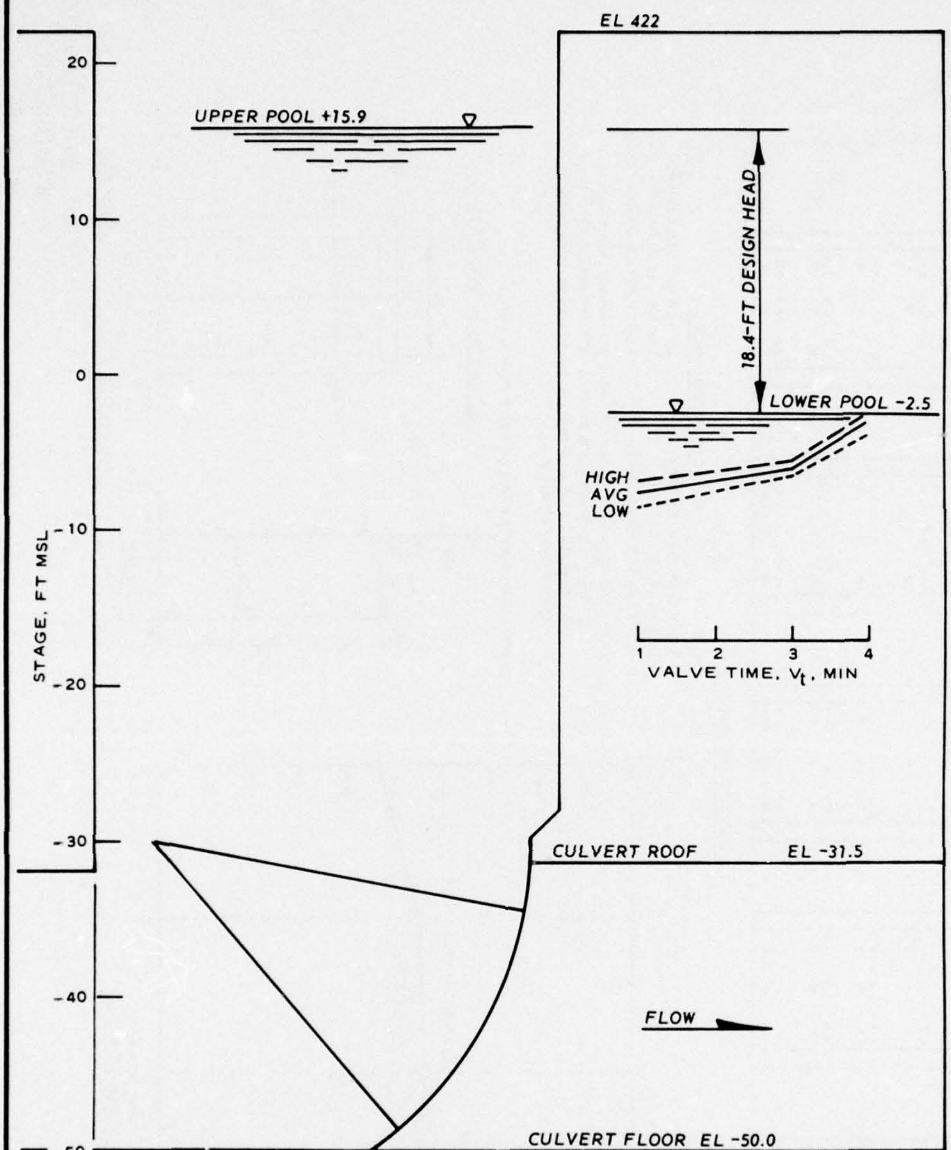


NOTE: STRUCTURE ELEVATIONS IN FEET MLG (MEAN LOW GULF DATUM)
UPPER AND LOWER POOL STAGES IN FEET MSL (ZERO MLG = -0.78 FEET MSL)

STA 6+80.00 D – 15+80.61 D

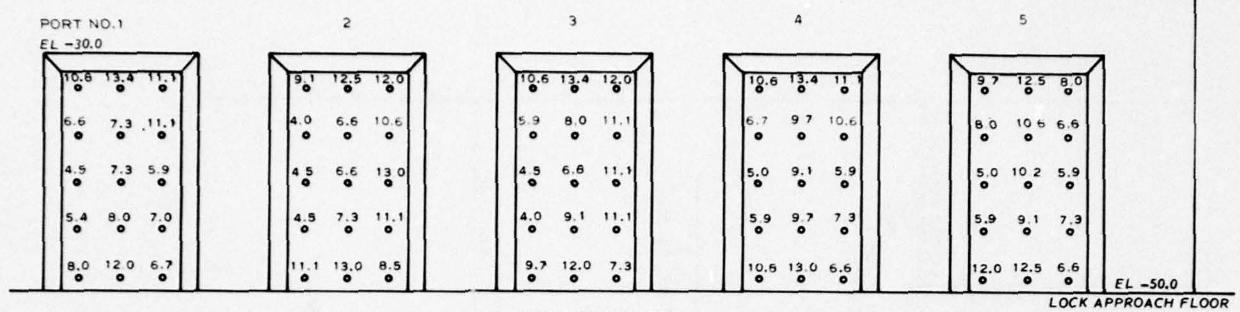
LEFT HALF PLAN OF FILLING AND EMPTYING SYSTEM

PIEZOMETER LOCATIONS
FILLING AND EMPTYING SYSTEM

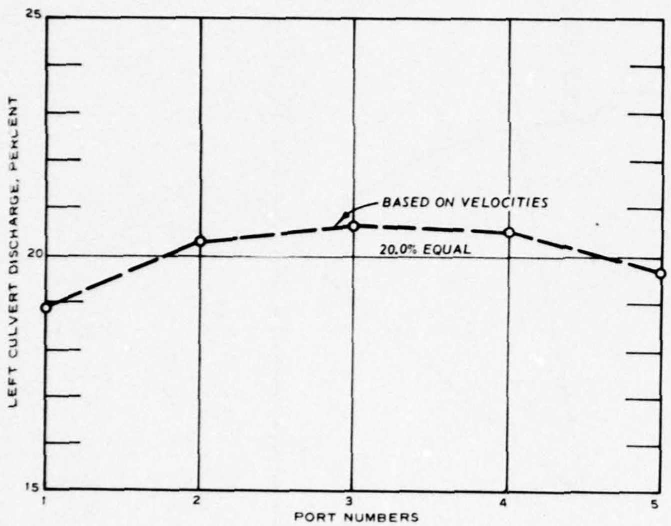


MINIMUM PRESSURES
DOWNSTREAM OF FILLING VALVES

ORIGINAL PORT ARRANGEMENT
18.4-FT DESIGN LIFT



VELOCITY DISTRIBUTION



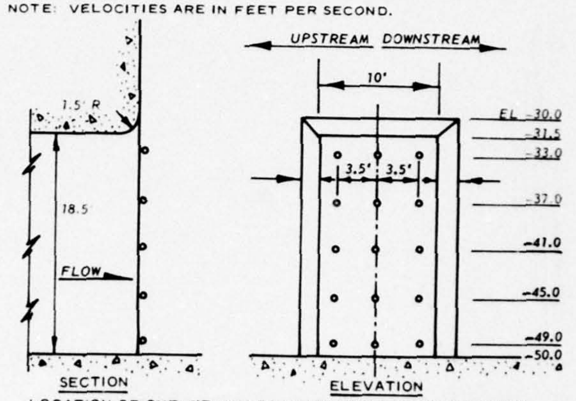
FLOW DISTRIBUTION

TEST CONDITIONS

LOCK CHAMBER *EL* +13.3	UPPER VALVES CLOSED
LOWER POOL *EL* -2.5	LOWER VALVES FULLY OPEN
UPPER MITER GATES OPEN	LOWER MITER GATES CLOSED

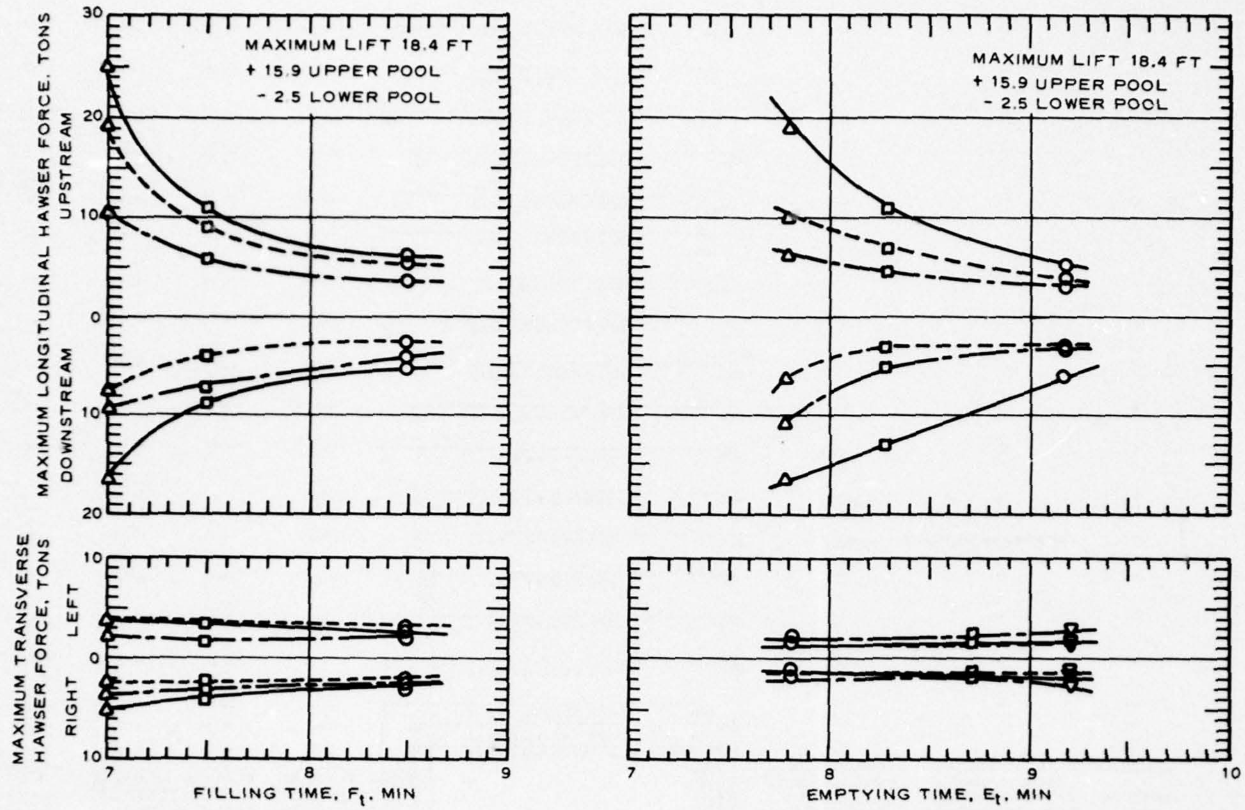
THIS CONDITION SIMULATES MAXIMUM DISCHARGE ±13,700 CFS DURING A 1-MIN VALVE SCHEDULE EMPTYING OPERATION WITH INITIAL LOCK CHAMBER *EL* +15.9 AND LOWER POOL *EL* -2.5 (18.4-FT DIFFERENTIAL)

NOTE: VELOCITIES ARE IN FEET PER SECOND.



LOCATION OF OUTLET MANIFOLD VELOCITY MEASUREMENTS

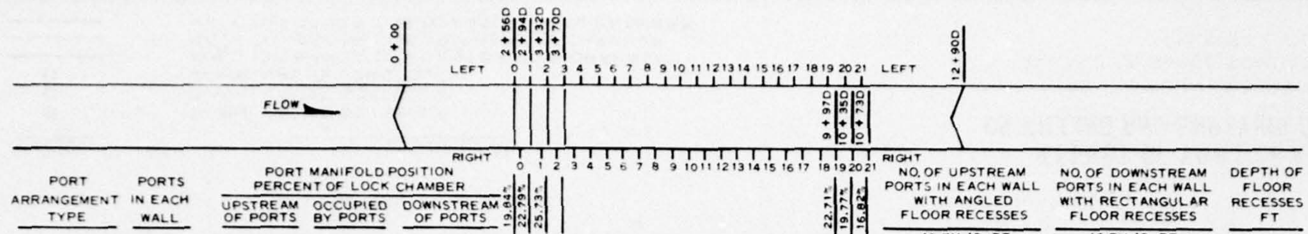
LEFT WALL OUTLET MANIFOLD
FLOW DISTRIBUTION
ORIGINAL DESIGN



SYMBOL	DESCRIPTION
△	1-MIN VALVE SCHEDULE
□	2-MIN VALVE SCHEDULE
○	4-MIN VALVE SCHEDULE
———	FULL (24) BARGE TOW CENTERED IN CHAMBER
– – –	HALF (12) BARGE TOW UPSTREAM IN CHAMBER
—·—	HALF (12) BARGE TOW DOWNSTREAM IN CHAMBER

EFFECT OF TOW SIZE AND POSITION ON FILLING AND EMPTYING CHARACTERISTICS

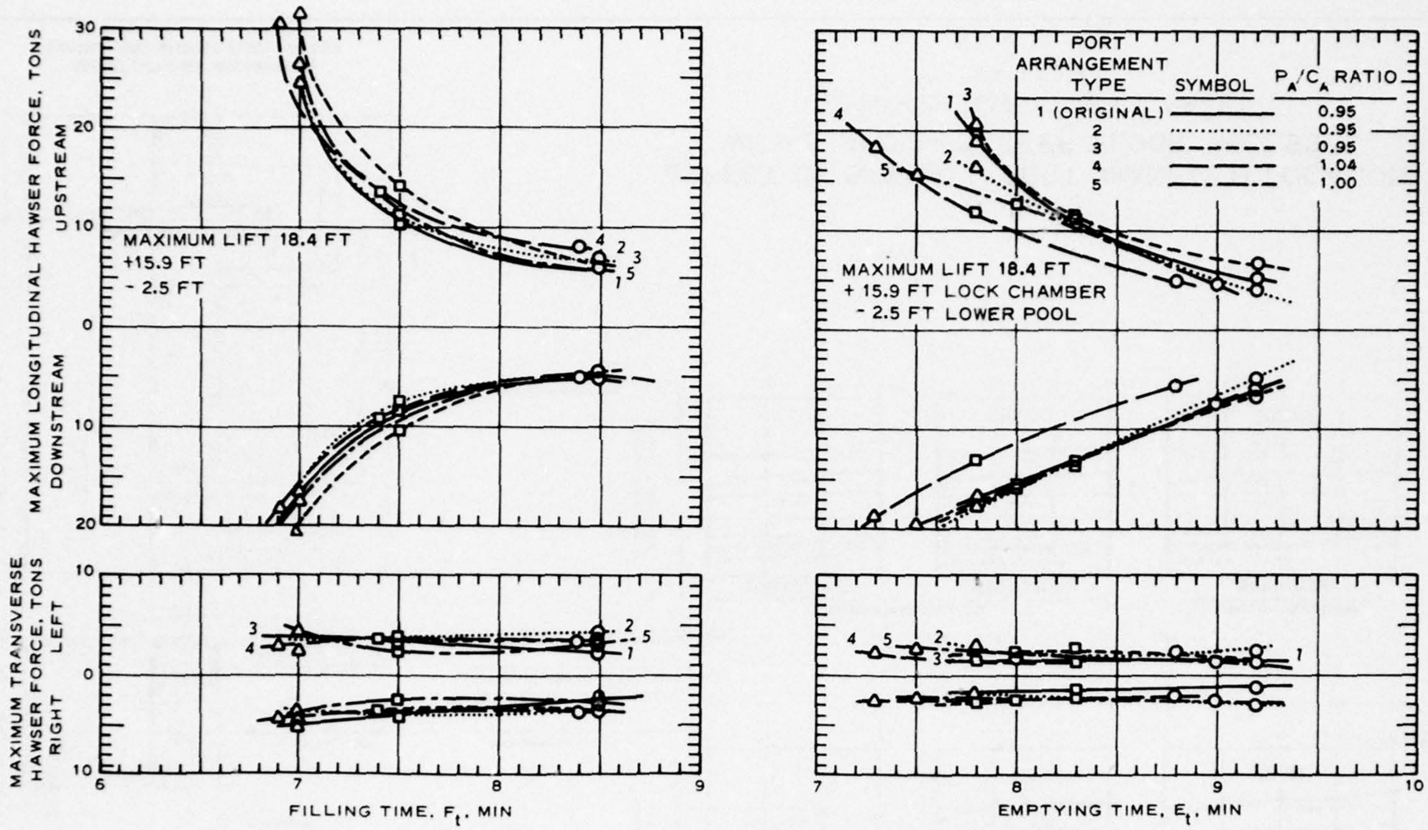
TYPE 1 (ORIGINAL) PORT ARRANGEMENT
24- AND 12-BARGE TOWS AT 12-FT DRAFT
18.4-FT LIFT



PORT ARRANGEMENT TYPE	PORTS IN EACH WALL	PORT MANIFOLD POSITION PERCENT OF LOCK CHAMBER: UPSTREAM OF PORTS	OCCUPIED BY PORTS	DOWNSTREAM OF PORTS		NO. OF UPSTREAM PORTS IN EACH WALL WITH ANGLED FLOOR RECESSES 15 BY 15-FT	NO. OF DOWNSTREAM PORTS IN EACH WALL WITH RECTANGULAR FLOOR RECESSES 15 BY 15-FT	DEPTH OF FLOOR RECESSES FT
1	20	22.79	57.44	19.77	1L TYPE 1 (ORIGINAL) PA/CA = 0.95 20R	—	—	—
2	20	25.73	57.44	16.82	2L TYPE 2 PA/CA = 0.95 21R	—	—	—
3	20	19.84	57.44	22.71	0L TYPE 3 PA/CA = 0.95 19R	—	—	—
4	22	19.84	63.33	16.82	0L TYPE 4 PA/CA = 1.04 21R	—	—	—
5	21	22.79	60.39	16.82	1L TYPE 5 PA/CA = 1.00 21R	—	—	—
6	19	28.69	54.49	16.82	3L TYPE 6 PA/CA = 0.90 21R	—	—	—
7	20	25.73	57.44	16.82	2L TYPE 7 PA/CA = 0.95 21R	ALL PORTS RECTANGULAR RECESSES		2
8	20	25.73	57.44	16.82	2L TYPE 8 PA/CA =0.95 21R	7	13	2
9	22	19.84	63.33	16.82	0L TYPE 9 PA/CA = 1.04 21R	7	15	2
10	20	25.73	57.44	16.82	2L TYPE 10 PA/CA = 0.95 21R	9	11	2
11	22	19.84	63.33	16.82	0L TYPE 11 PA/CA = 1.04 21R	11	11	2
12	22	19.84	63.33	16.82	0L TYPE 12 PA/CA = 1.04 21R	5	17	2
13	20	22.79	57.44	19.77	1L TYPE 13 PA/CA = 0.95 20R	7	13	2
14	20	19.84	57.44	22.71	0L TYPE 14 PA/CA = 0.95 19R	7	13	2
15 (RECOMMENDED)	20	22.79	57.44	19.77	1L TYPE 15 PA/CA = 0.95 20R	7	13	3
16		25.73	57.44	16.82	2L TYPE 16 PA/CA = 0.95 21R	7	13	3
17	20	19.84	57.44	22.71	0L TYPE 17 PA/CA = 0.95 19R	7	13	3
18	20	22.79	57.44	19.77	1L TYPE 18 PA/CA = 0.95 20R	6	14	3
19	20	22.79	57.44	19.77	1L TYPE 19 PA/CA = 0.95 20R	8	12	3
20	20	22.79	57.44	19.77	1L TYPE 20 PA/CA = 0.95 20R	9	11	3

PORT MANIFOLD ARRANGEMENTS
TYPES 1(ORIGINAL)-20

PLATE 14

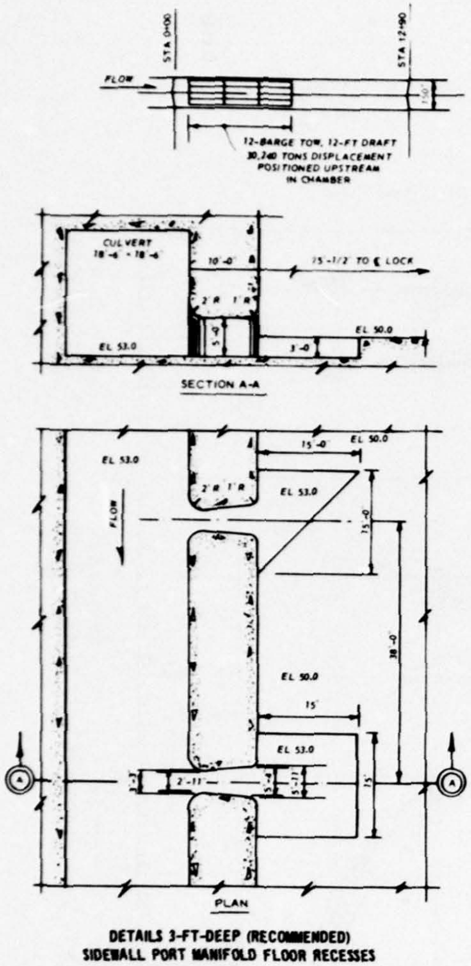


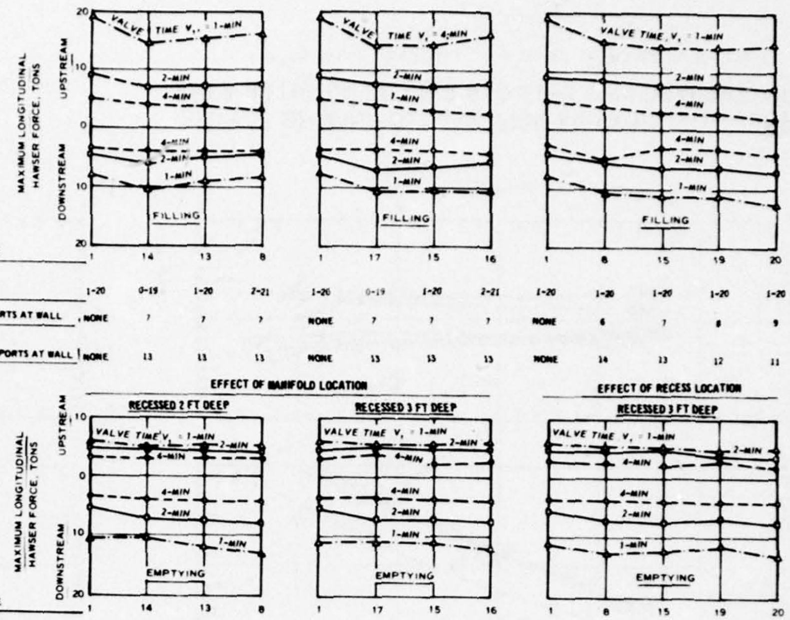
LEGEND

SYMBOL	VALVE TIME, MIN
△	1
□	2
○	4

EFFECT OF MANIFOLD POSITION AND PORT-TO-CULVERT-AREA RATIO ON FILLING AND EMPTYING CHARACTERISTICS

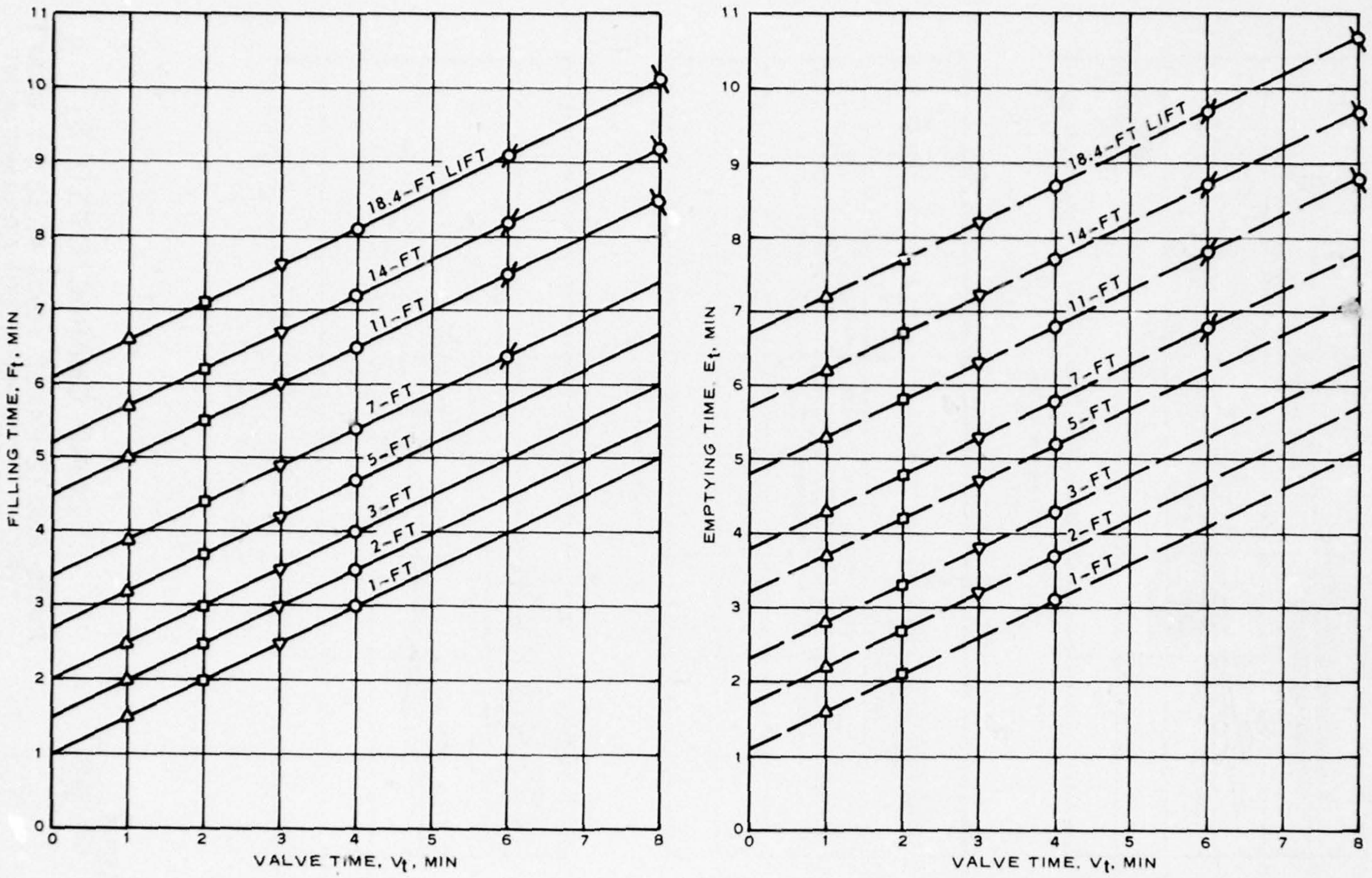
TYPES 1 (ORIGINAL)-5 PORT ARRANGEMENTS
24-BARGE TOW AT 12-FT DRAFT
18.4-FT LIFT





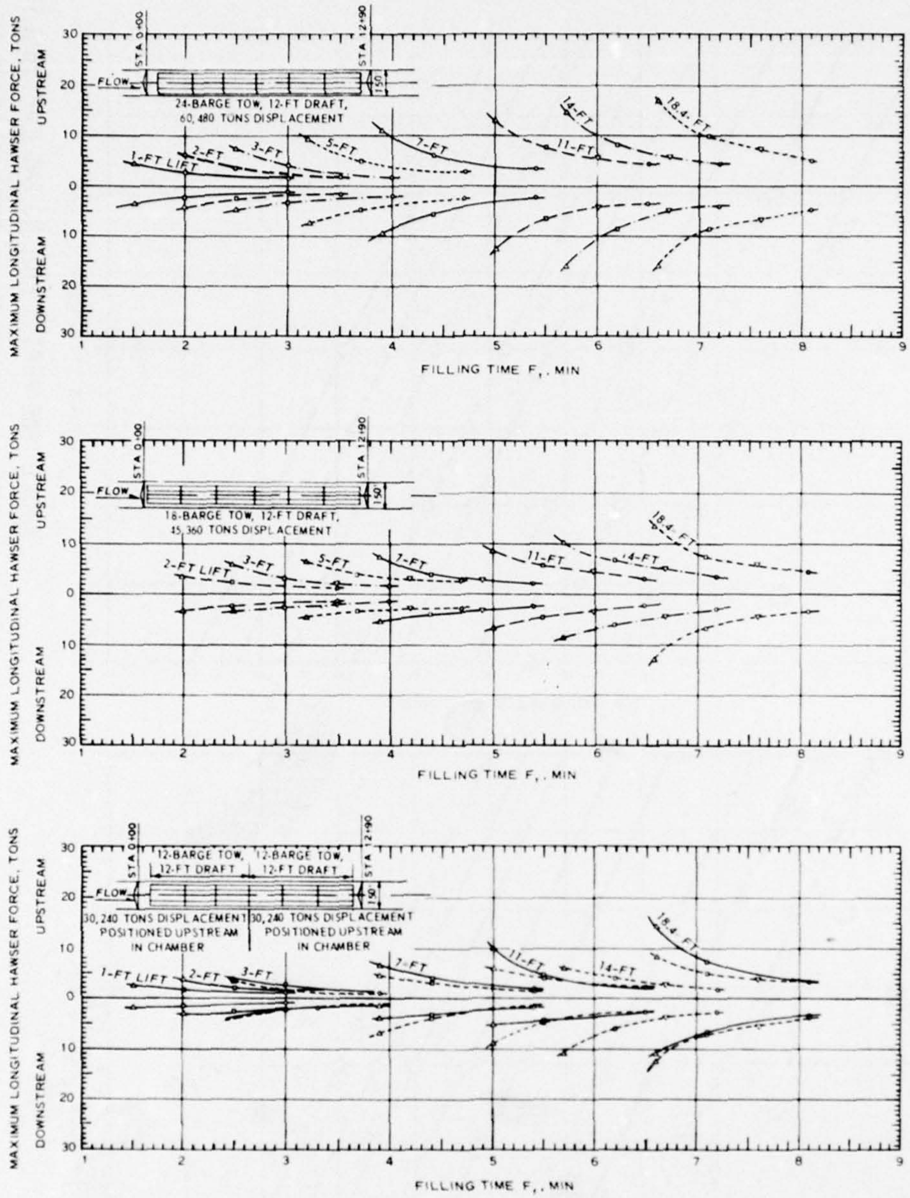
PORT ARRANGEMENT TYPE	1	14	13	8	1	17	15	16	1	8	15	19	20
WALL PORTS OPEN	1-20	0-19	1-20	2-21	1-20	0-19	1-20	2-21	1-20	1-20	1-20	1-20	1-20
RECESSED UPSTREAM WALL PORTS AT WALL	NONE	7	7	7	NONE	7	7	7	NONE	6	7	8	9
RECESSED DOWNSTREAM WALL PORTS AT WALL	NONE	13	13	13	NONE	13	13	13	NONE	14	13	12	11

EFFECT OF SIDEWALL PORT MANIFOLD LOCATION
WITH 2- AND 3-FT-DEEP FLOOR RECESSES
12-BARGE TOW AT 12-FT DRAFT
18.4-FT LIFT



VALVE TIME VERSUS FILLING AND EMPTYING TIME

TYPE-15 (RECOMMENDED) PORT ARRANGEMENT
1.0- TO 18.4-FT LIFTS



LEGEND

SYMBOL	VALVE TIME, MIN
△	1
□	2
▽	3
○	4

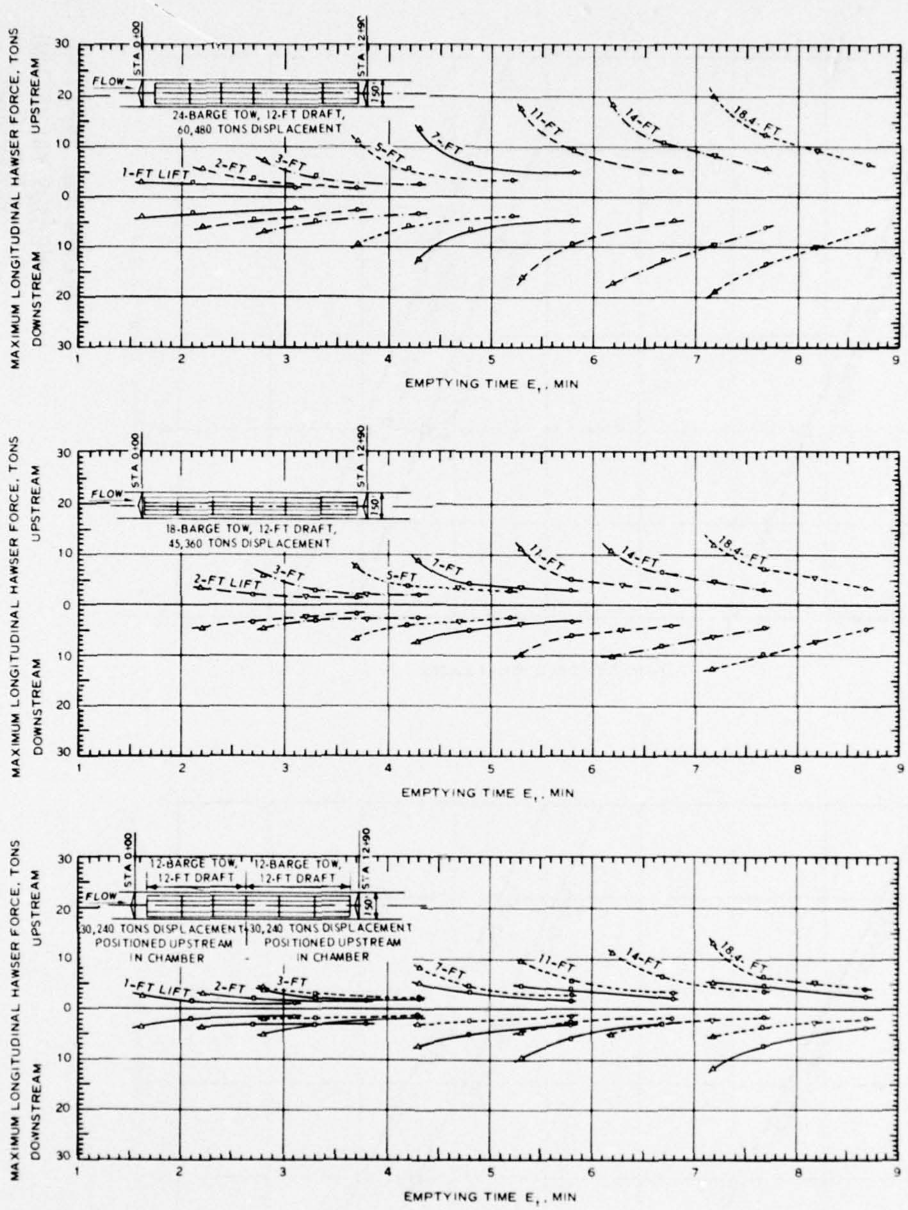
——— 12- BARGE TOW UPSTREAM

– – – – 12- BARGE TOW DOWNSTREAM

FILLING CHARACTERISTICS

24-, 18-, AND 12-BARGE TOWS AT 12-FT DRAFT
TYPE 15 (RECOMMENDED) ARRANGEMENT

1.0- TO 18.4-FT LIFTS



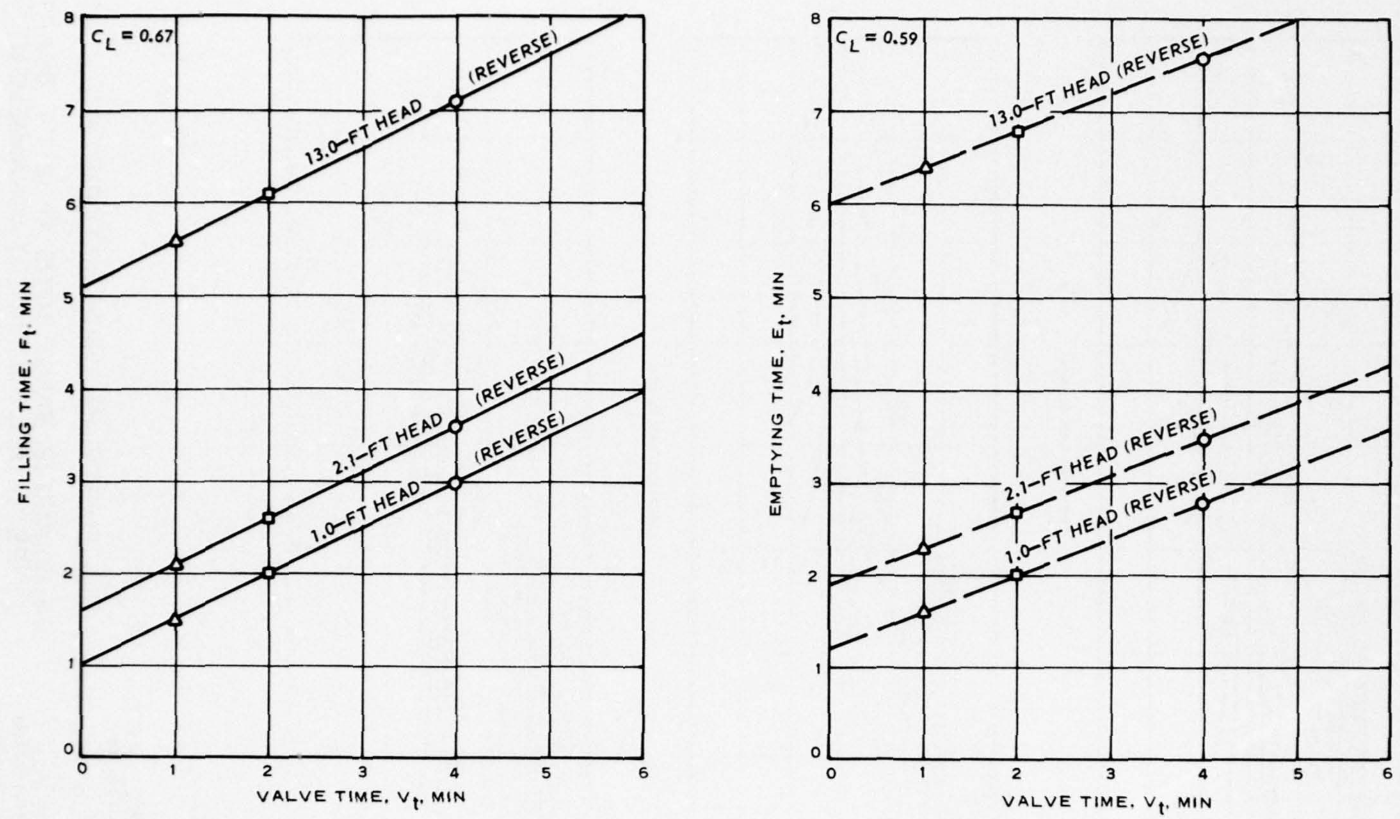
LEGEND

SYMBOL	VALVE TIME, MIN
Δ	1
□	2
∇	3
○	4
———	12- BARGE TOW UPSTREAM
-·-·- - - -	12- BARGE TOW DOWNSTREAM

EMPTYING CHARACTERISTICS

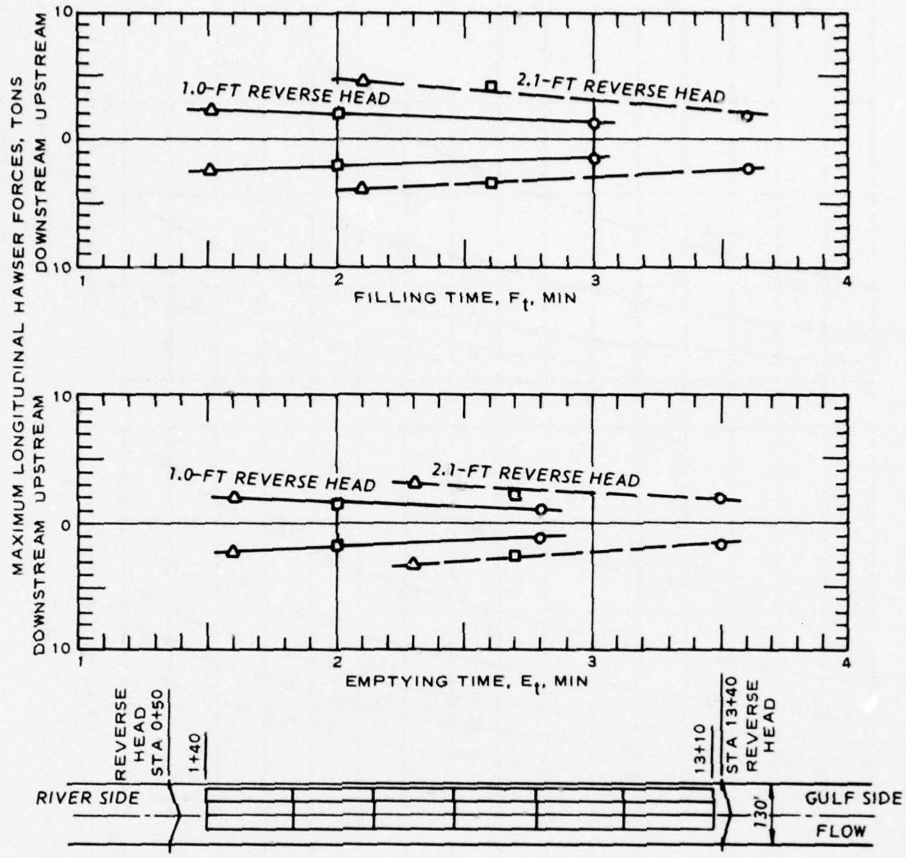
24-, 18-, AND 12-BARGE TOWS AT 12-FT DRAFT
TYPE 15 (RECOMMENDED) ARRANGEMENT

1.0- TO 18.4-FT LIFTS



FILLING AND EMPTYING TIME VERSUS VALVE TIME

REVERSE HEADS
TYPE 15 PORT ARRANGEMENT



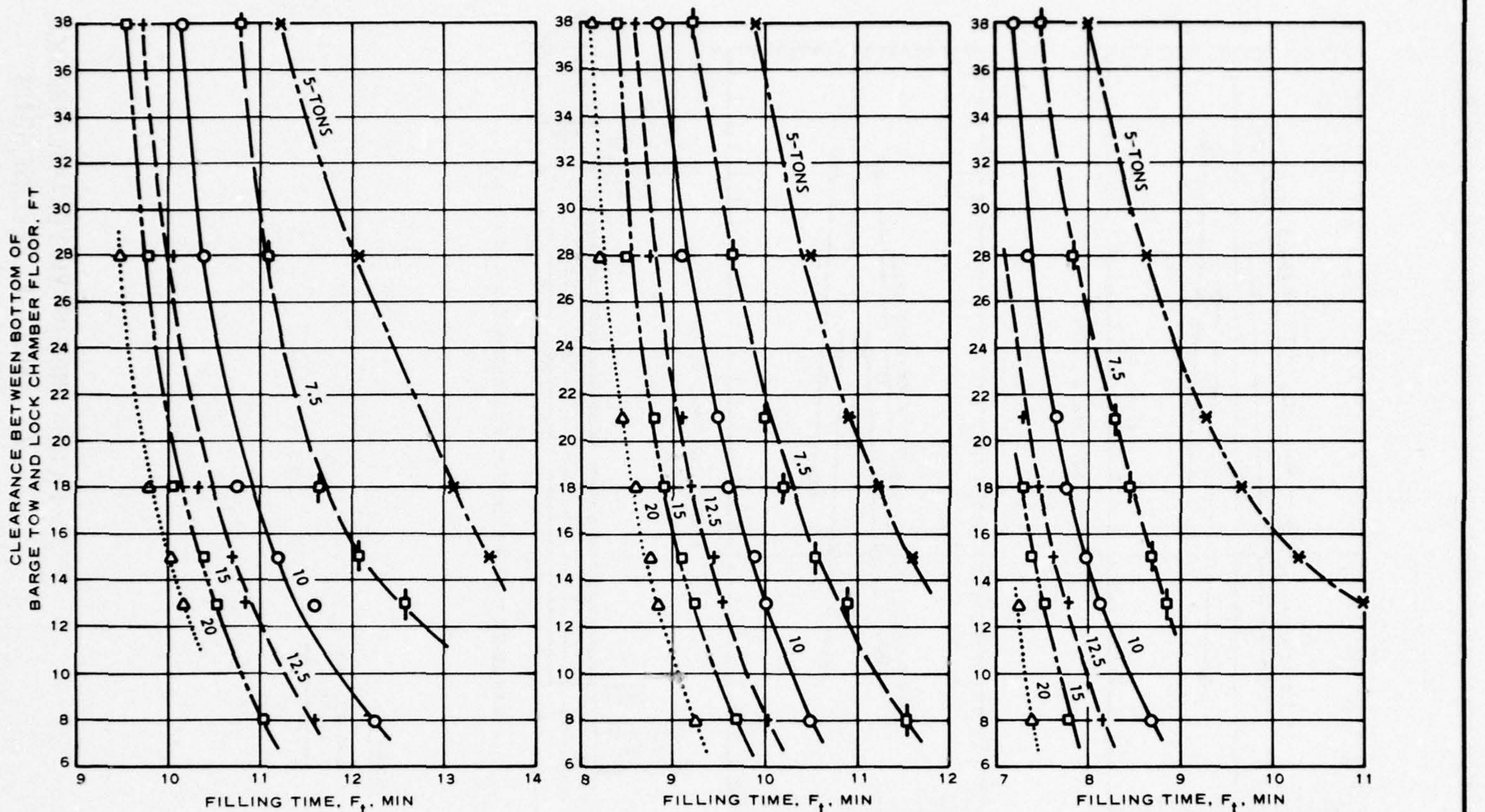
18-BARGE TOW, 12-FT DRAFT, 45,360-TON DISPLACEMENT

LEGEND

SYMBOL	VALVE TIME V_t, MIN
△	1
□	2
○	4

FILLING AND EMPTYING CHARACTERISTICS
2.1- AND 1.0-FT REVERSE HEADS
18-BARGE TOW, 12-FT DRAFT

TYPE 15 PORT ARRANGEMENT

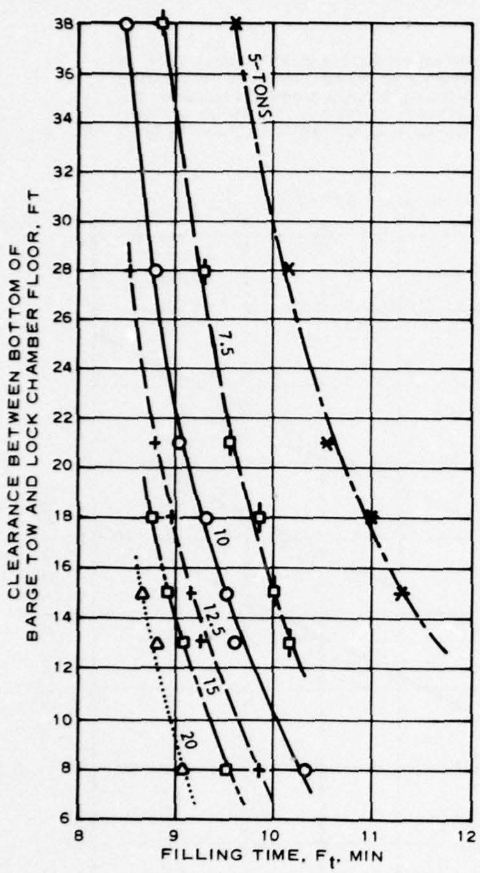


40-FT LIFT
BARGE TOW DISPLACEMENT 60,480 TONS
24-BARGE TOW AT 12-FT DRAFT

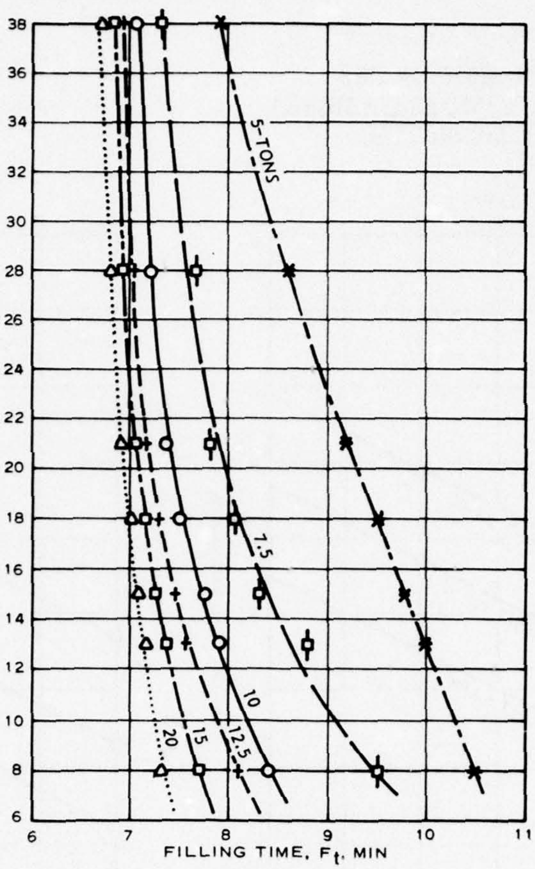
30-FT LIFT

20-FT LIFT

TYPE 15 (RECOMMENDED) SYSTEM
24-BARGE TOW AT 12-FT DRAFT
UPSTREAM END OF TOW AT STATION 0+30

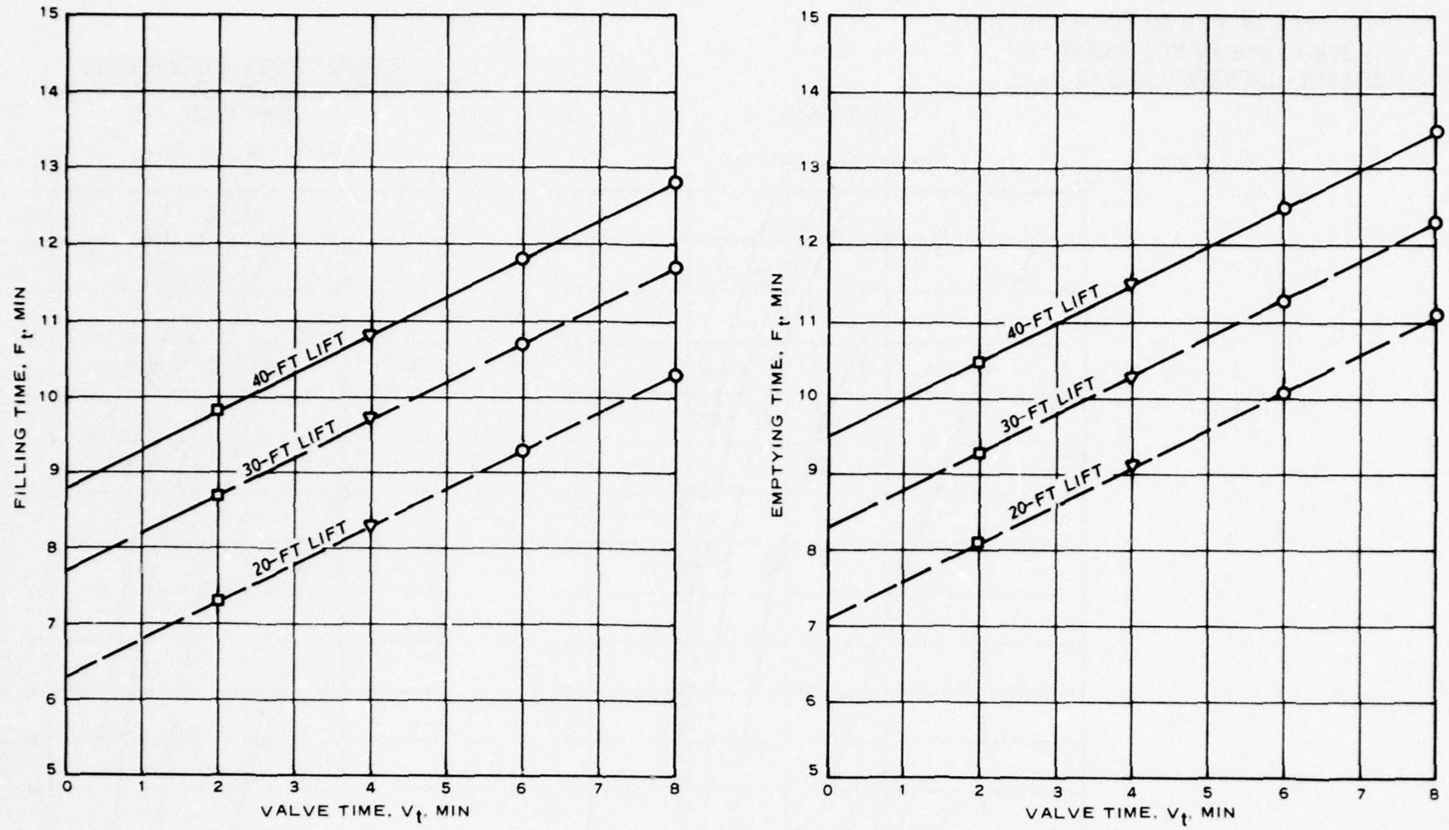


30-FT LIFT
BARGE TOW DISPLACEMENT, 44,240 TONS
24-BARGE TOW AT 9-FT DRAFT



20-FT LIFT

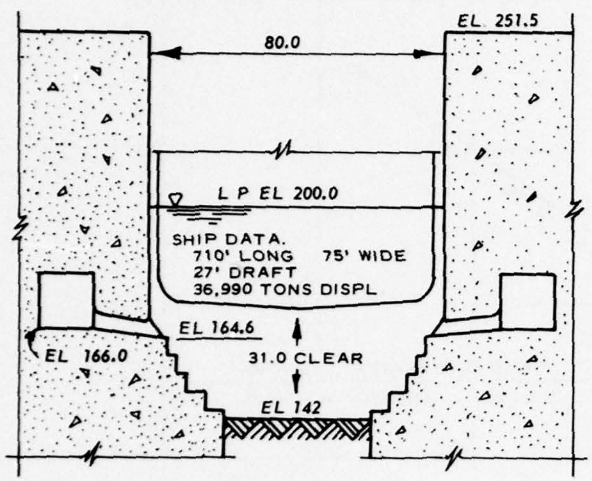
TYPE 15 (RECOMMENDED) SYSTEM
24-BARGE TOW AT 9-FT DRAFT
UPSTREAM END OF TOW AT STATION 0+30



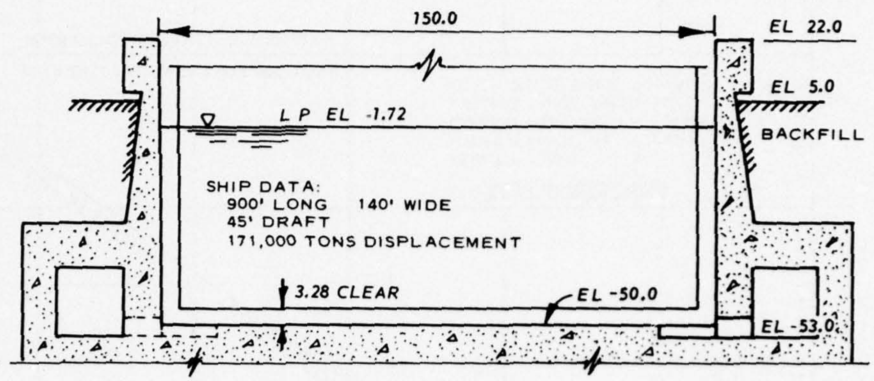
NOTE: THIS PLATE MAY BE USED WITH PLATES 21 AND 22 TO SELECT VALVE TIME APPROPRIATE TO OBTAIN HAWSER FORCE WITHIN A PARTICULAR LIMIT WITH CLEARANCE UNDER 9- AND 12-FT DRAFT TOW VARYING FROM 8 TO 38 FT

FILLING AND EMPTYING TIMES
VERSUS VALVE TIMES, 20-, 30-, AND 40-FT LIFTS
CWIS NO. 31076 GENERALIZED TEST

WITH TYPE 15 (RECOMMENDED) SYSTEM

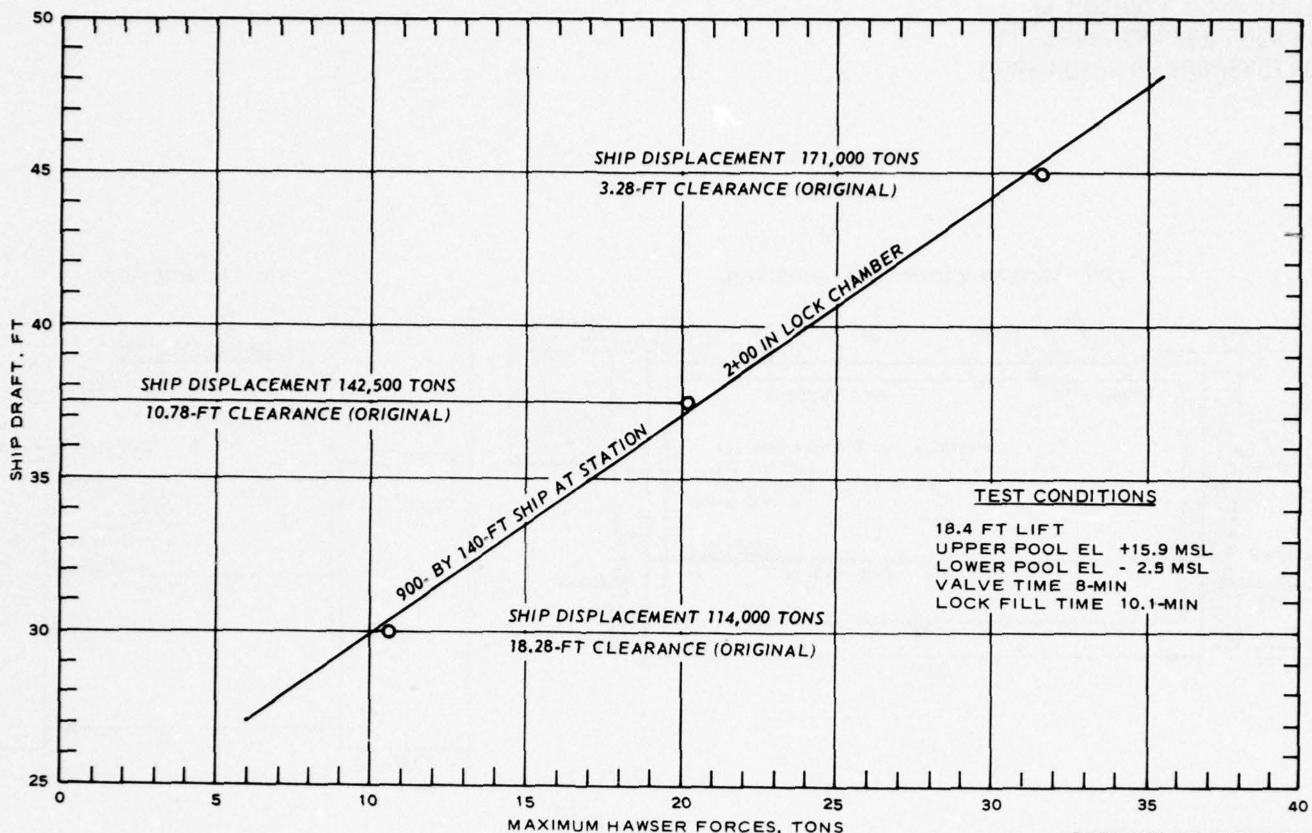


EISENHOWER LOCK



MISSISSIPPI RIVER-GULF OUTLET LOCK

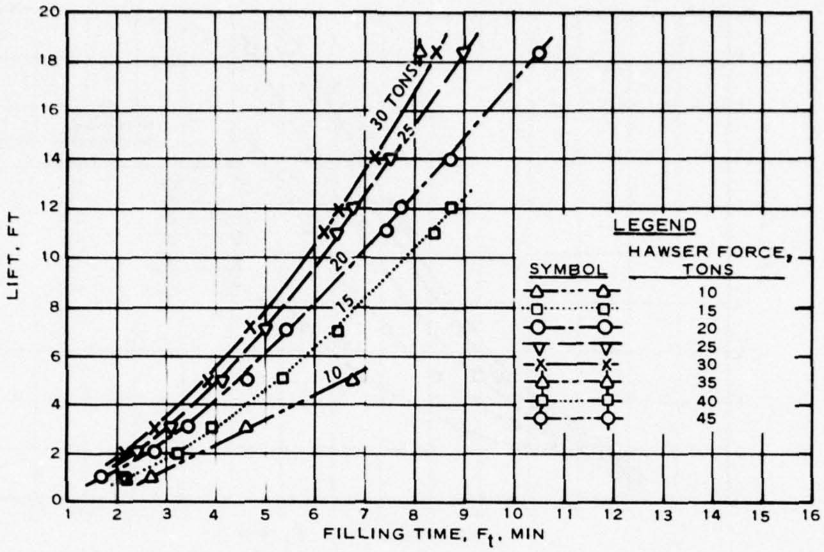
COMPARISON OF SUBMERGENCES AND CLEARANCES OVER LOCK FLOORS IN SIDEWALL PORT SYSTEMS



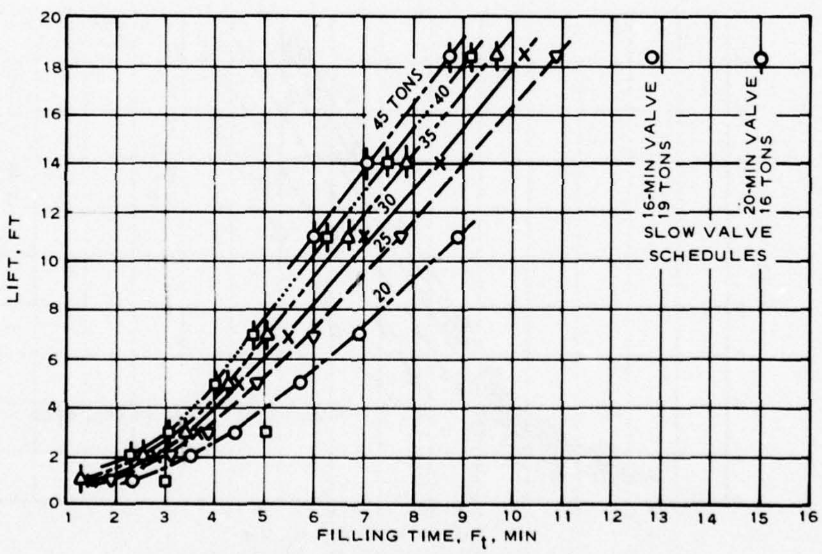
NOTE: CLEARANCE IS THE DISTANCE IN FEET BETWEEN THE BOTTOM OF THE SHIP AND FLOOR OF LOCK CHAMBER

EFFECT OF SHIP DRAFT AND DISPLACEMENT ON MAXIMUM HAWSER FORCES DURING FILLING

18.4-FT LIFT, MINIMUM STAGES
TYPE 15 PORT ARRANGEMENT



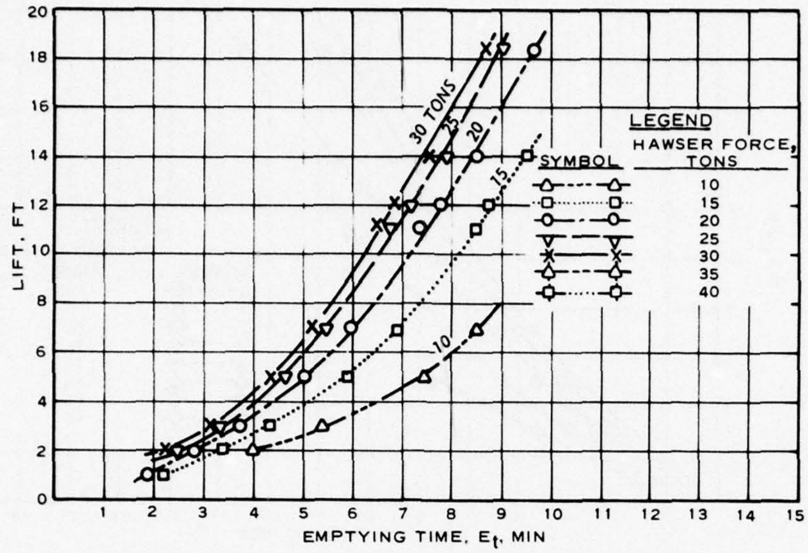
37.5-FT DRAFT SHIP WITH 142,500-TON DISPLACEMENT



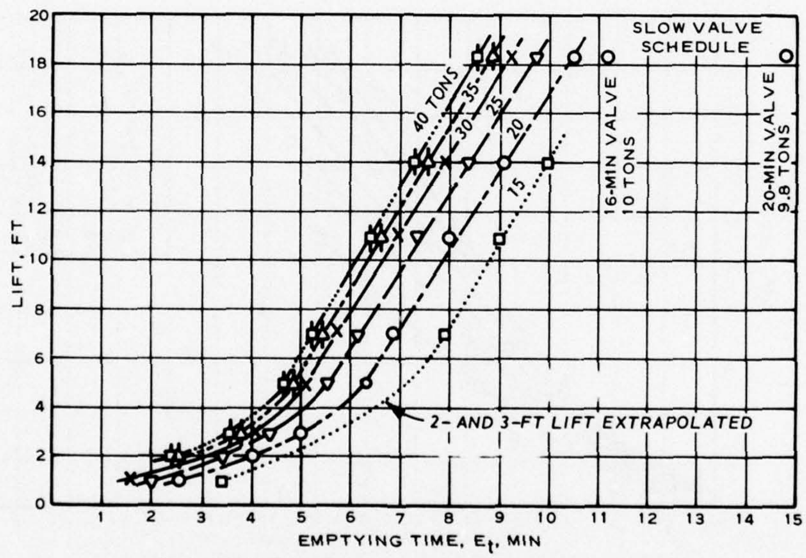
45-FT DRAFT SHIP WITH 171,000-TON DISPLACEMENT

FILLING TIME REQUIRED TO KEEP HAWSER FORCES WITHIN 10, 15, 20, 25, 30, 35, 40, AND 45 TONS

TYPE 15 PORT ARRANGEMENT
900-FT SHIP WITH BOW AT STA 2+00
37.5- AND 45-FT DRAFTS
1.0- TO 18.4-FT LIFTS



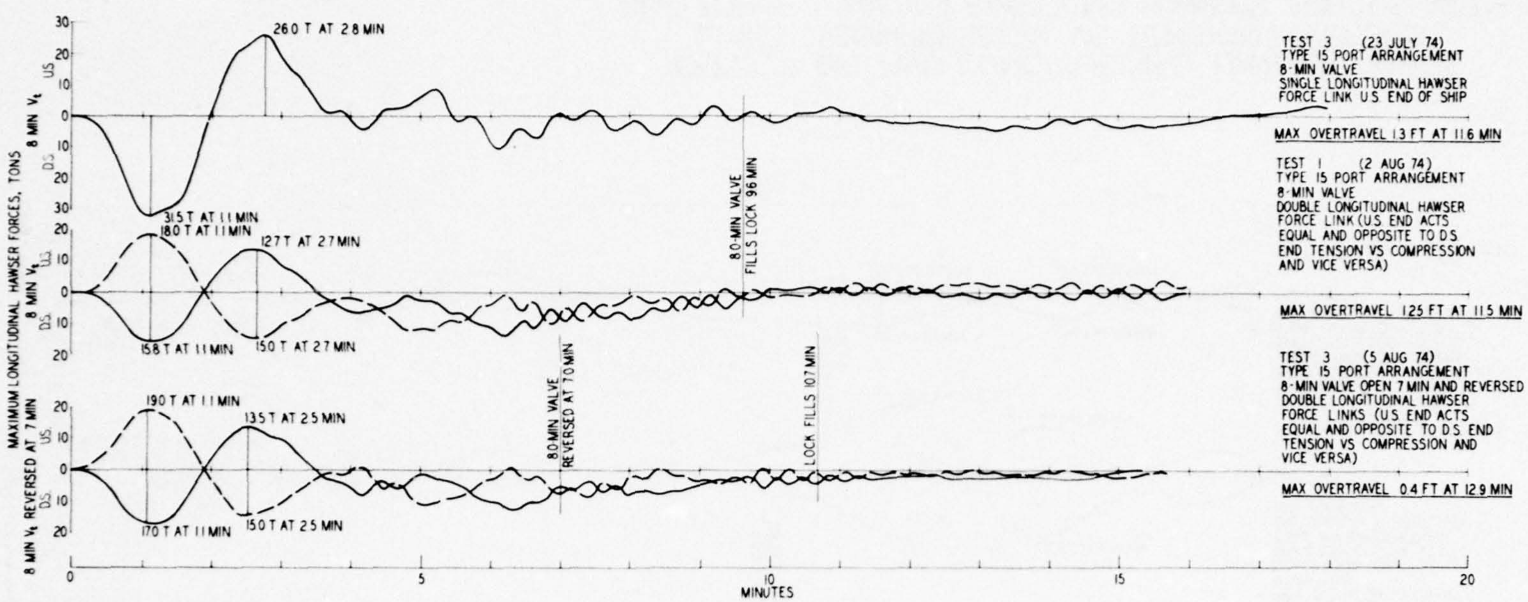
37.5- FT DRAFT SHIP WITH 142,500-TON DISPLACEMENT



45-FT DRAFT SHIP WITH 171,000-TON DISPLACEMENT

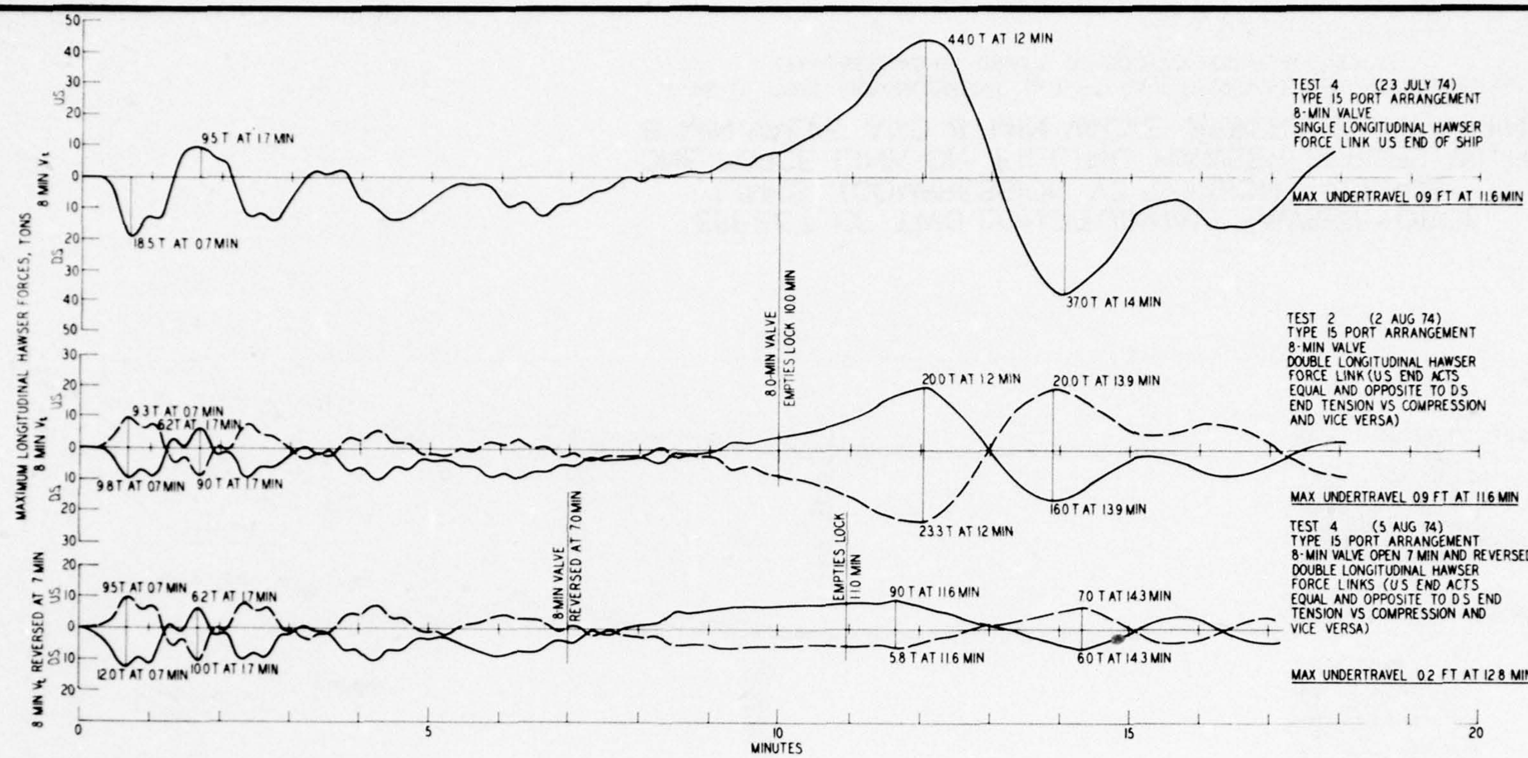
EMPTYING TIME REQUIRED TO KEEP HAWSER FORCES WITHIN 10, 15, 20, 25, 30, 35, AND 40 TONS

TYPE 15 PORT ARRANGEMENT
900-FT SHIP WITH BOW AT STA 2+00
37.5- AND 45-FT DRAFTS
1.0- TO 18.4-FT LIFTS



EFFECT OF TWO LONGITUDINAL HAWSER FORCE LINKS (COMPRESSION VS TENSION) VERSUS ONE FORCE LINK ON FILLING HAWSER FORCES WITH 8-MIN VALVE AND 8-MIN VALVE REVERSED AT 7 MIN

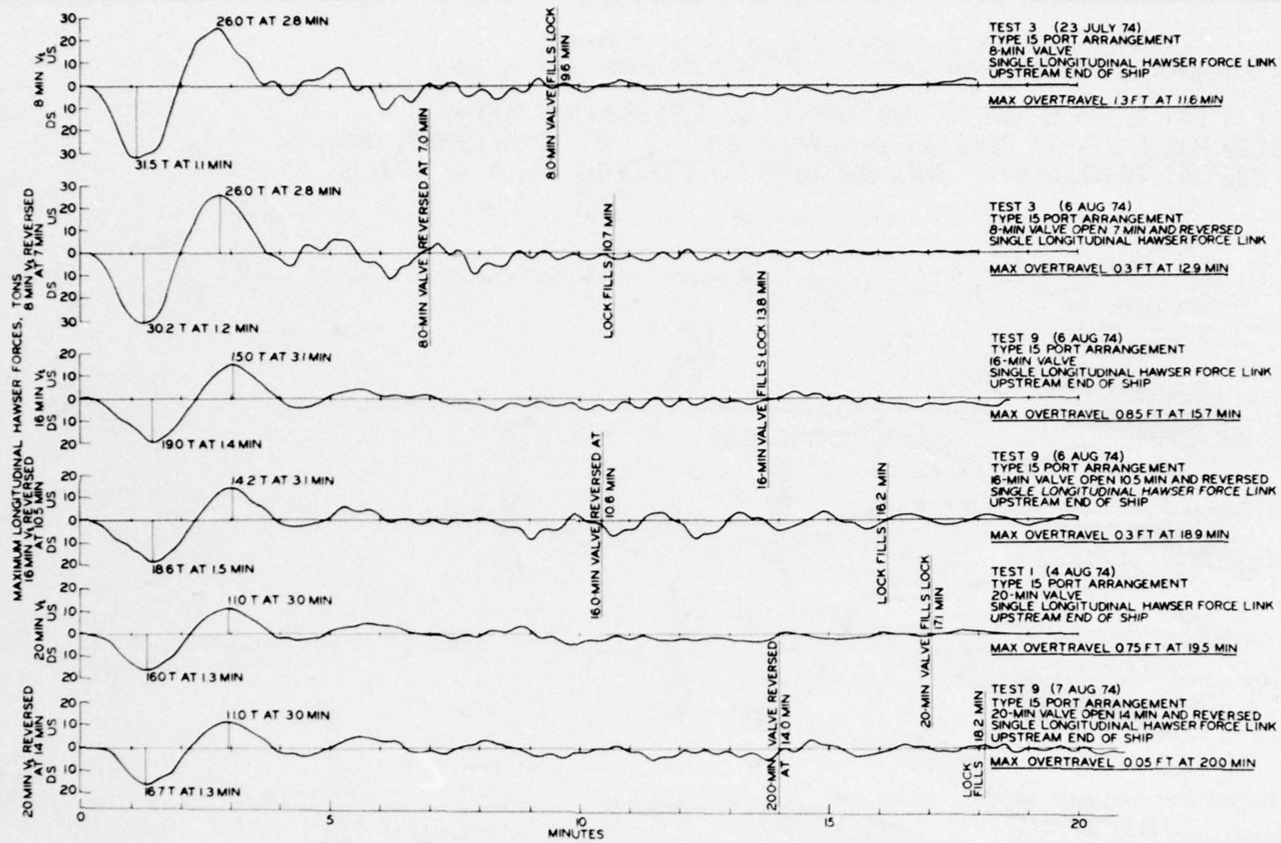
TYPE 15 PORT ARRANGEMENT, 18.4-FT LIFT (+15.9-2.5), SHIP CENTERED IN CHAMBER, 45-FT DRAFT (171,000-TON DISPLACEMENT)



EFFECT OF TWO LONGITUDINAL HAWSER FORCE LINKS (COMPRESSION VS TENSION) VERSUS ONE FORCE LINK ON EMPTYING HAWSER FORCES WITH 8-MIN VALVE AND 8-MIN VALVE REVERSED AT 7 MIN

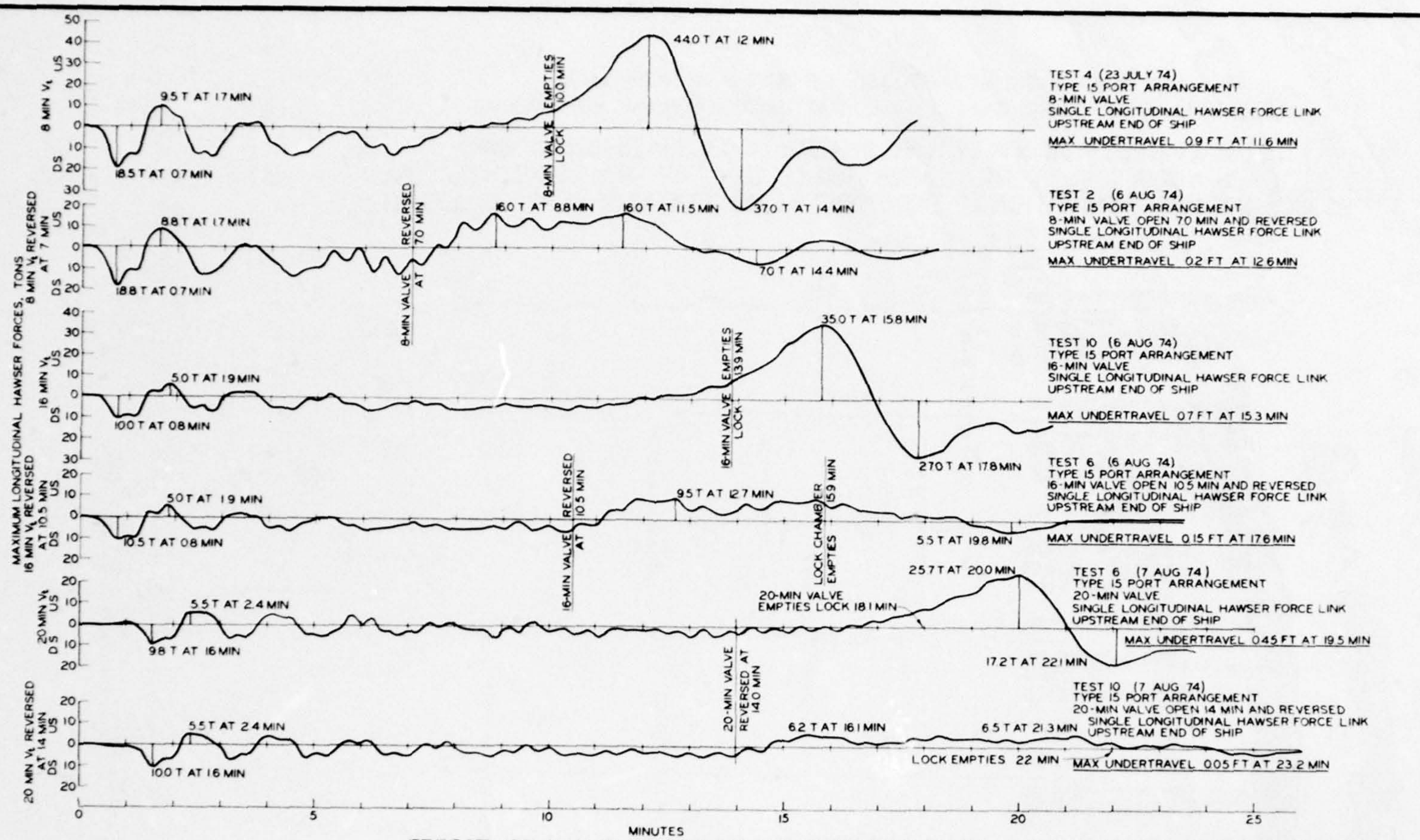
TYPE 15 PORT ARRANGEMENT, 18.4-FT LIFT (+15.9-2.5), SHIP CENTERED IN CHAMBER, 45-FT DRAFT (171,000-TON DISPLACEMENT)

PLATE 30



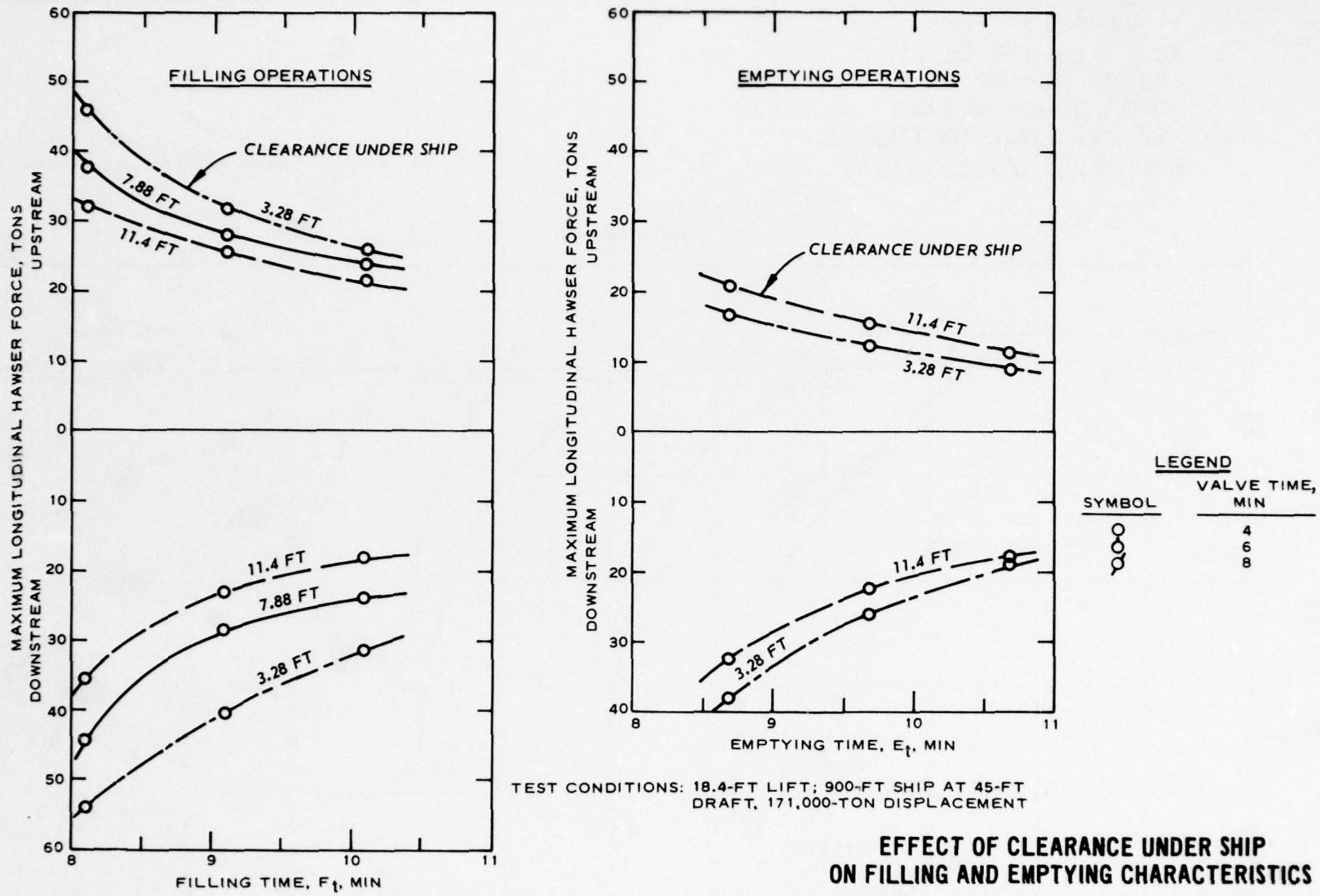
EFFECT OF VALVE SCHEDULE ON FILLING TIME, LONGITUDINAL HAWSER FORCES, AND OVERTRAVEL 8-, 16-, AND 20-MIN VALVE TIME VERSUS 8 MIN REVERSED AT 7 MIN, 16 MIN REVERSED AT 10.5 MIN, AND 20 MIN REVERSED AT 14 MIN

TYPE 15 PORT ARRANGEMENT, 18.4-FT LIFT (+15.9-2.5), SHIP CENTERED IN CHAMBER, 45-FT DRAFT (171,000-TON DISPLACEMENT)



EFFECT OF VALVE SCHEDULE ON EMPTYING TIME, LONGITUDINAL HAWSER FORCES, AND UNDERTRAVEL 8-, 16-, AND 20-MIN VALVE TIME VERSUS 8 MIN REVERSED AT 7 MIN, 16 MIN REVERSED AT 10.5 MIN, AND 20 MIN REVERSED AT 14 MIN

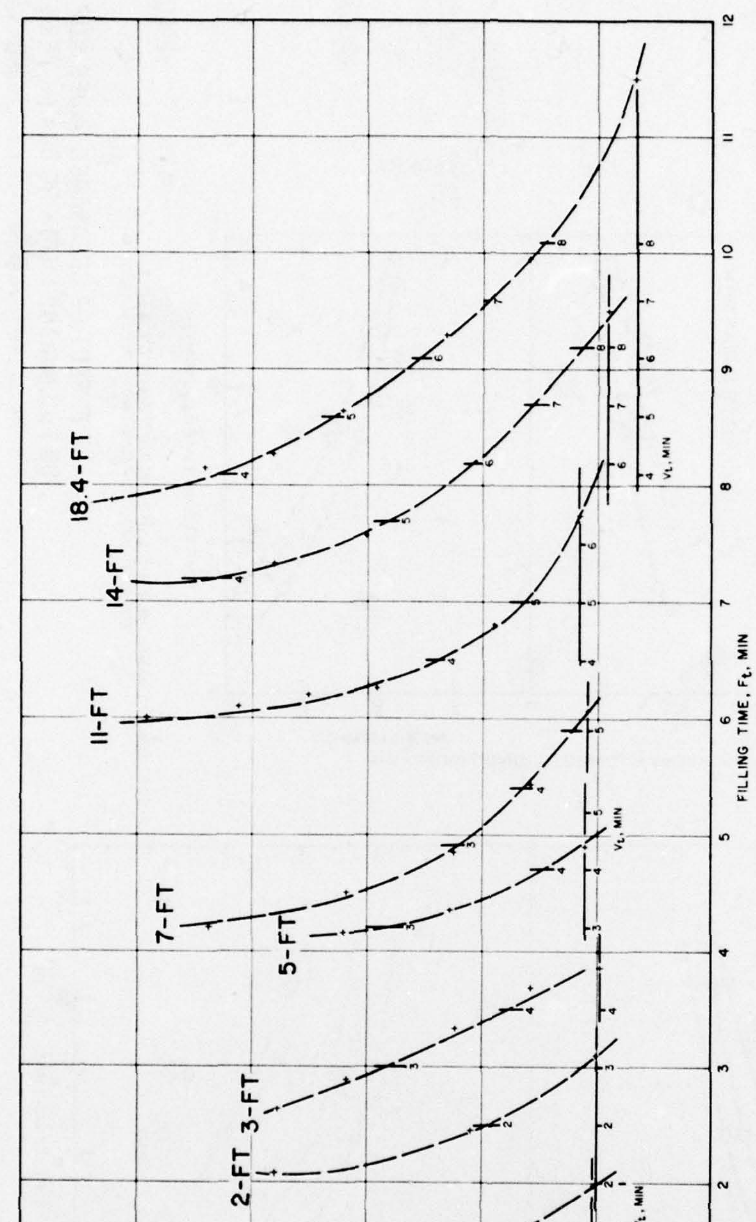
TYPE 15 PORT ARRANGEMENT, 18.4-FT LIFT (+15.9-2.5), SHIP CENTERED IN CHAMBER, 45-FT DRAFT (171,000-TON DISPLACEMENT)



TEST CONDITIONS: 18.4-FT LIFT; 900-FT SHIP AT 45-FT DRAFT, 171,000-TON DISPLACEMENT

EFFECT OF CLEARANCE UNDER SHIP ON FILLING AND EMPTYING CHARACTERISTICS

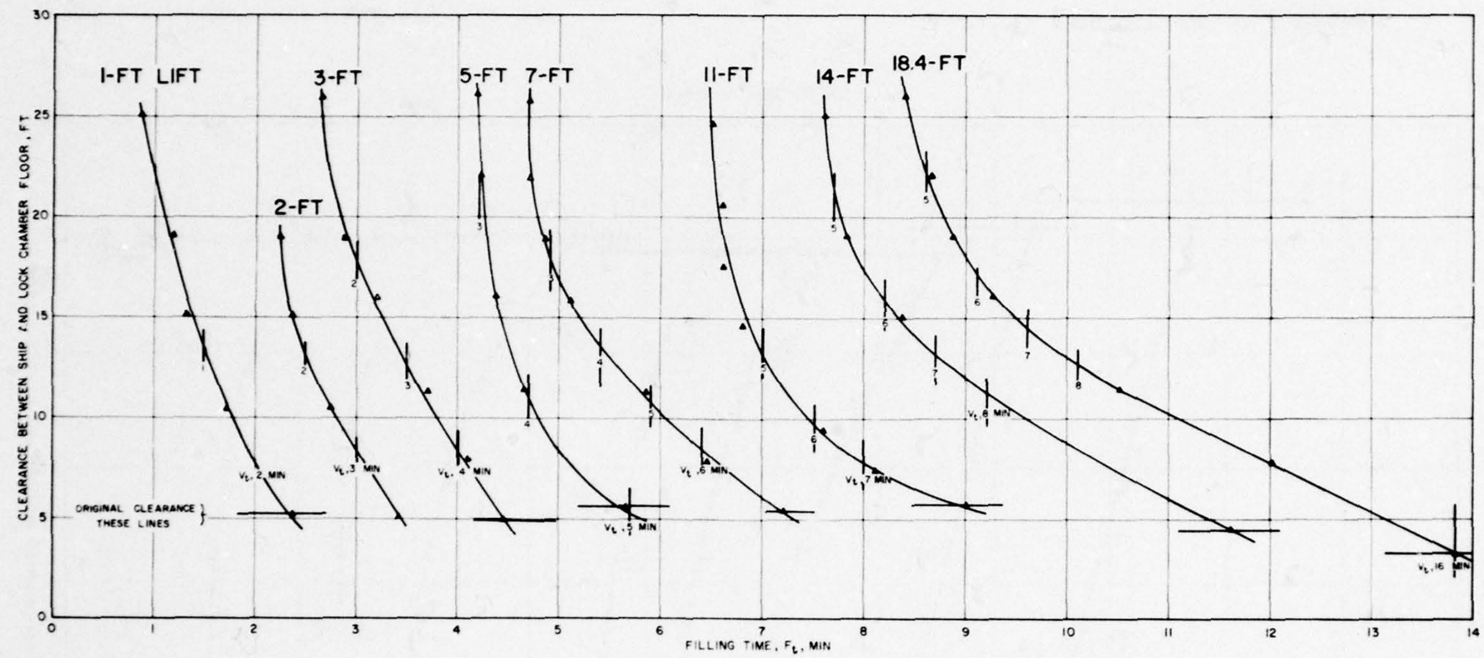
TYPE 15 (RECOMMENDED) PORT ARRANGEMENT



NOTE: 45-FT SHIP DRAFT WAS DISPLACEMENT OF 171,000 TONS

EFFECT OF CLEARANCE
ON FILLING TIMES FOR 25-TON
HAWSER FORCE LIMIT
WITH 45-FT DRAFT
1.0- TO 18.4-FT LIFTS

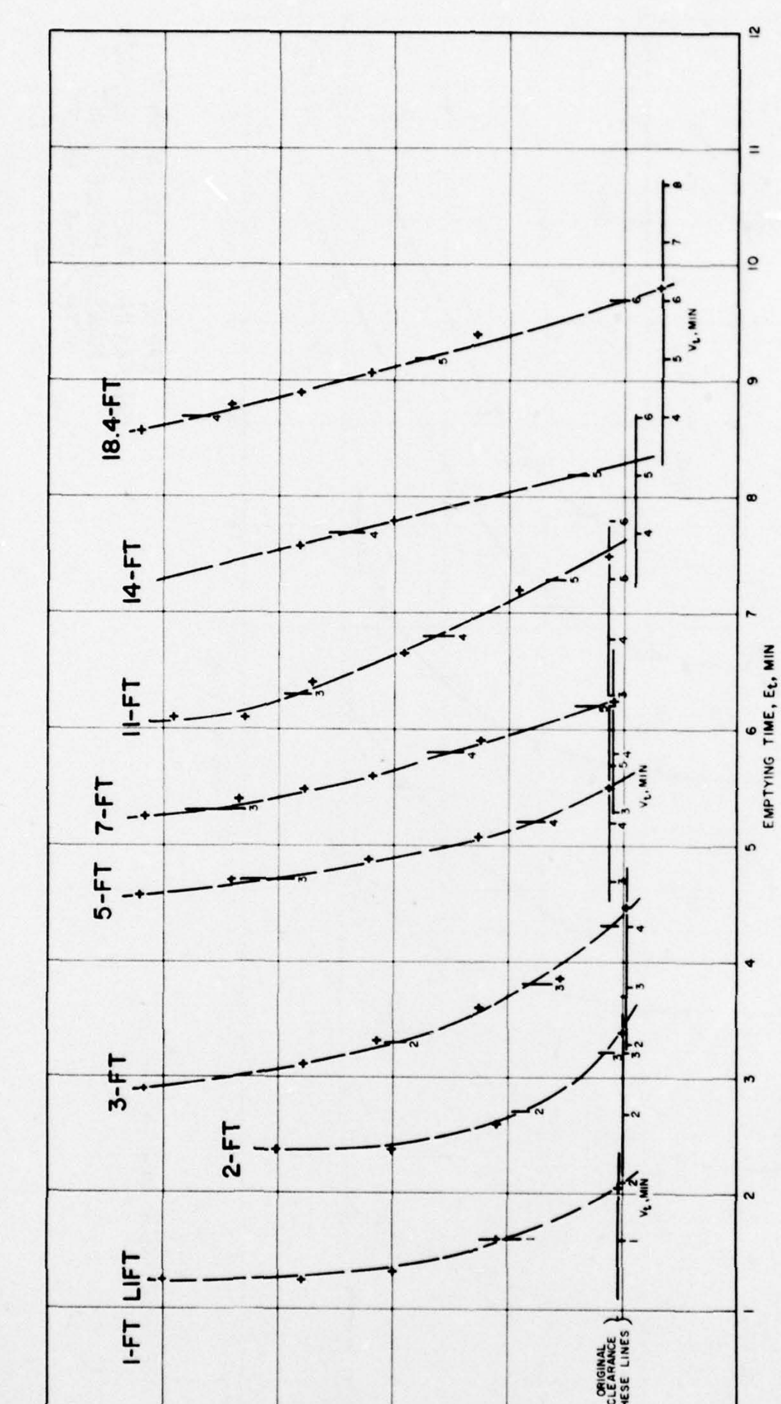
TYPE 15 PORT ARRANGEMENT



NOTE: 45-FT SHIP DRAFT WAS DISPLACEMENT OF 171,000 TONS

EFFECT OF CLEARANCE
ON FILLING TIMES FOR 20-TON
HAWSER FORCE LIMIT
WITH 45-FT DRAFT
1.0-TO 18.4-FT LIFTS

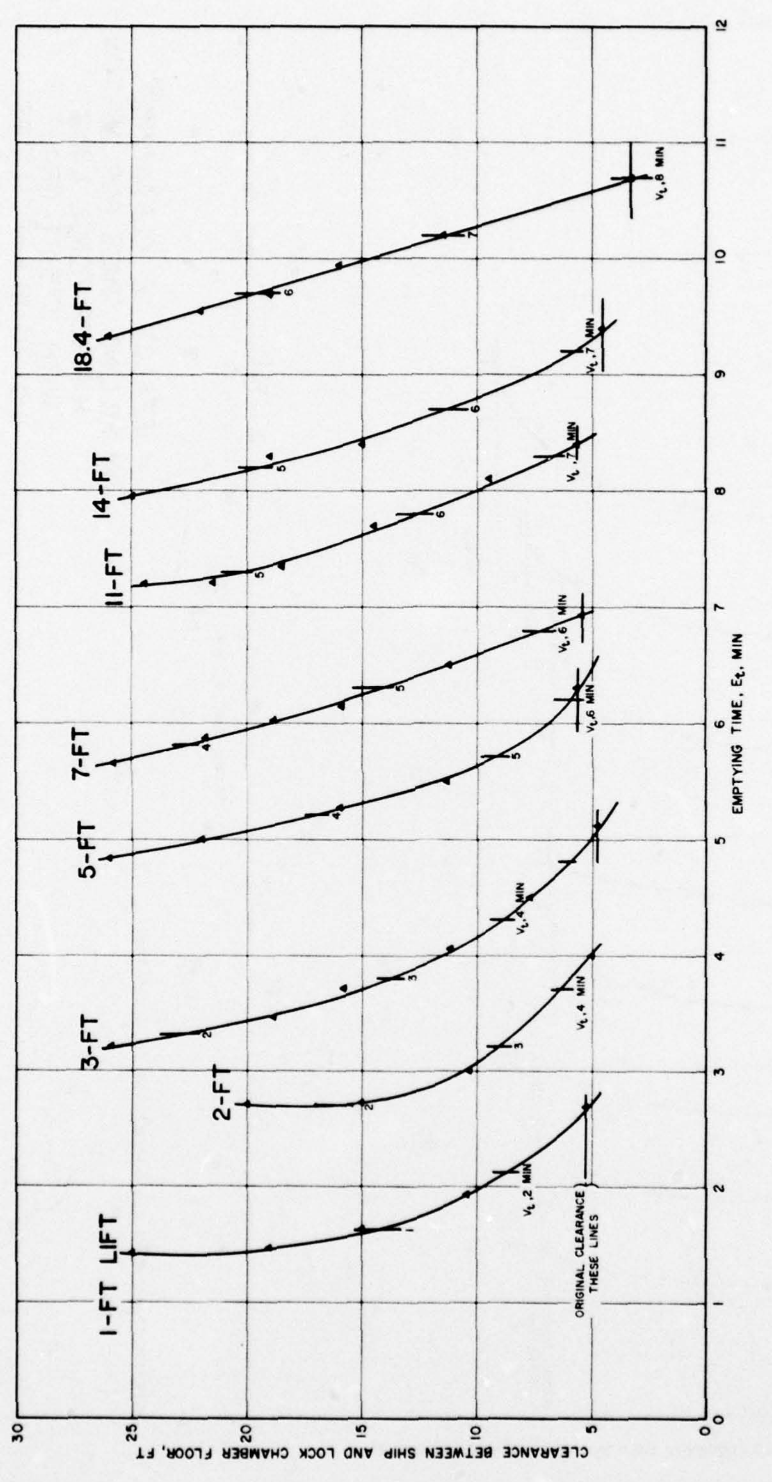
TYPE 15 PORT ARRANGEMENT



EFFECT OF CLEARANCE
ON EMPTYING TIMES FOR 25-TON
HAWSER FORCE LIMIT
WITH 45-FT DRAFT
1.0- TO 18.4-FT LIFTS

TYPE 15 PORT ARRANGEMENT

PLATE 36

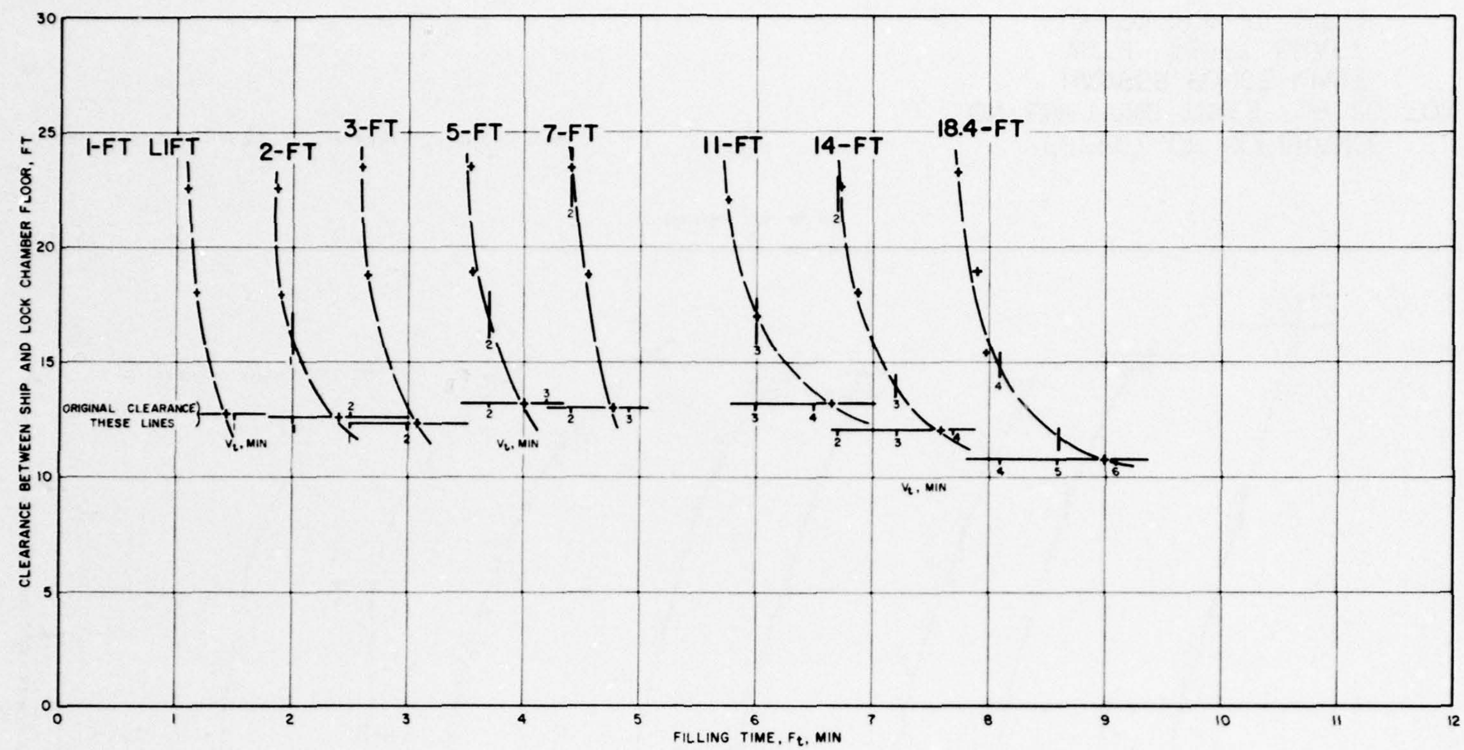


NOTE: 45-FT SHIP DRAFT WAS DISPLACEMENT OF 171,000 TONS.

EFFECT OF CLEARANCE
ON EMPTYING TIMES FOR 20-TON
HAWSER FORCE LIMIT
WITH 45-FT DRAFT
1.0- TO 18.4-FT LIFTS

TYPE 15 PORT ARRANGEMENT

PLATE 37

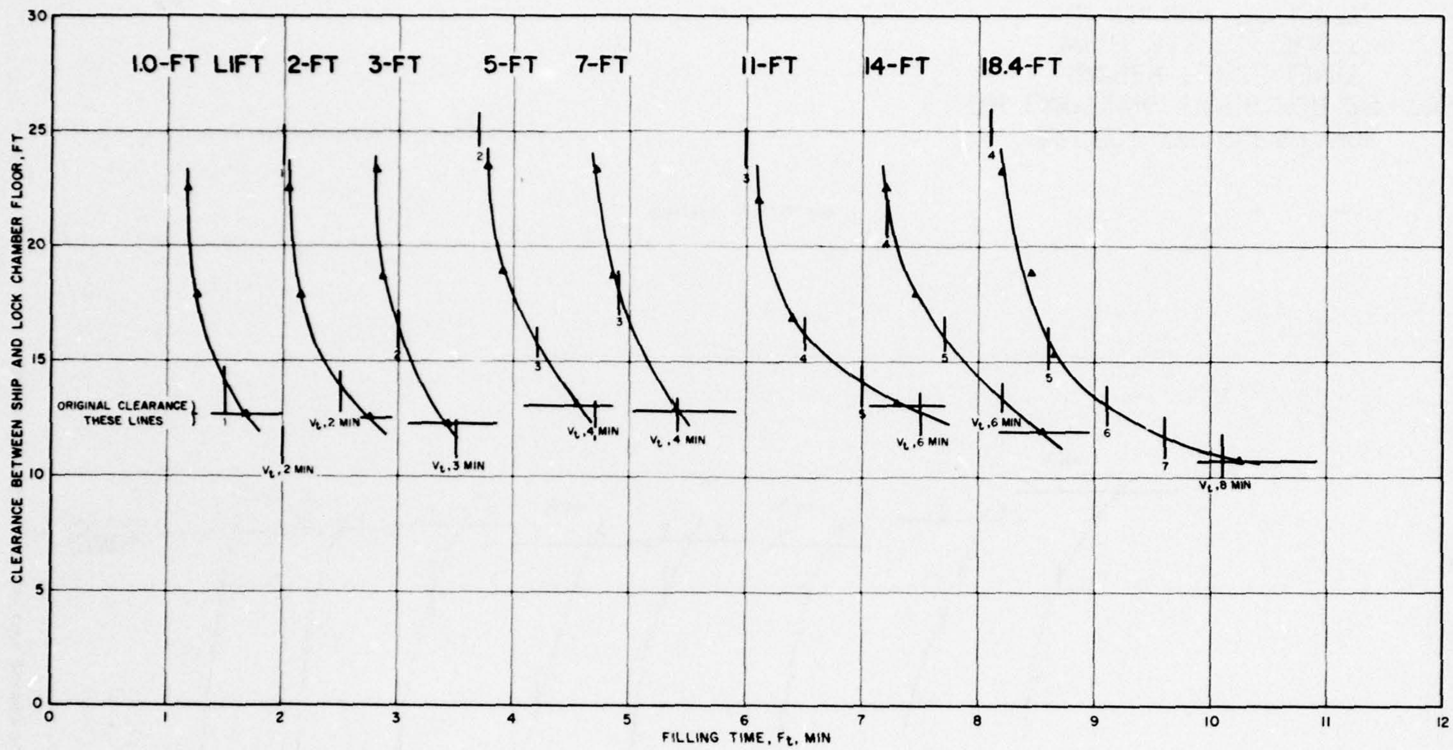


NOTE: 37.5-FT SHIP DRAFT WAS DISPLACEMENT OF 142,500 TONS.

EFFECT OF CLEARANCE
ON FILLING TIMES FOR 25-TON
HAWSER FORCE LIMIT
WITH 37.5-FT DRAFT
1.0- TO 18.4-FT LIFTS

TYPE 15 PORT ARRANGEMENT

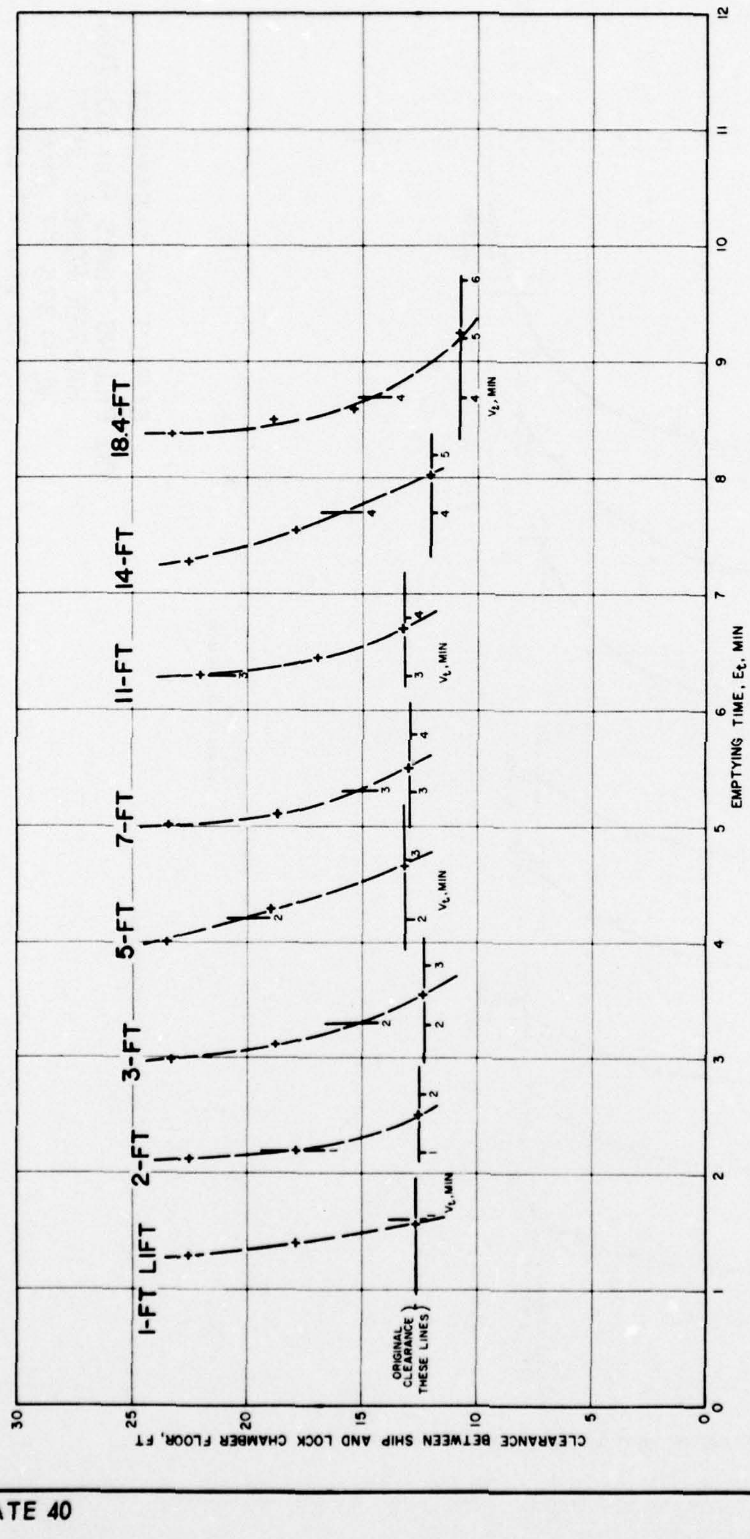
PLATE 38



NOTE: 37.5-FT SHIP DRAFT WAS DISPLACEMENT OF 142,500 TONS.

EFFECT OF CLEARANCE
ON FILLING TIMES FOR 20-TON
HAWSER FORCE LIMIT
WITH 37.5-FT DRAFT
1.0- TO 18.4-FT LIFTS

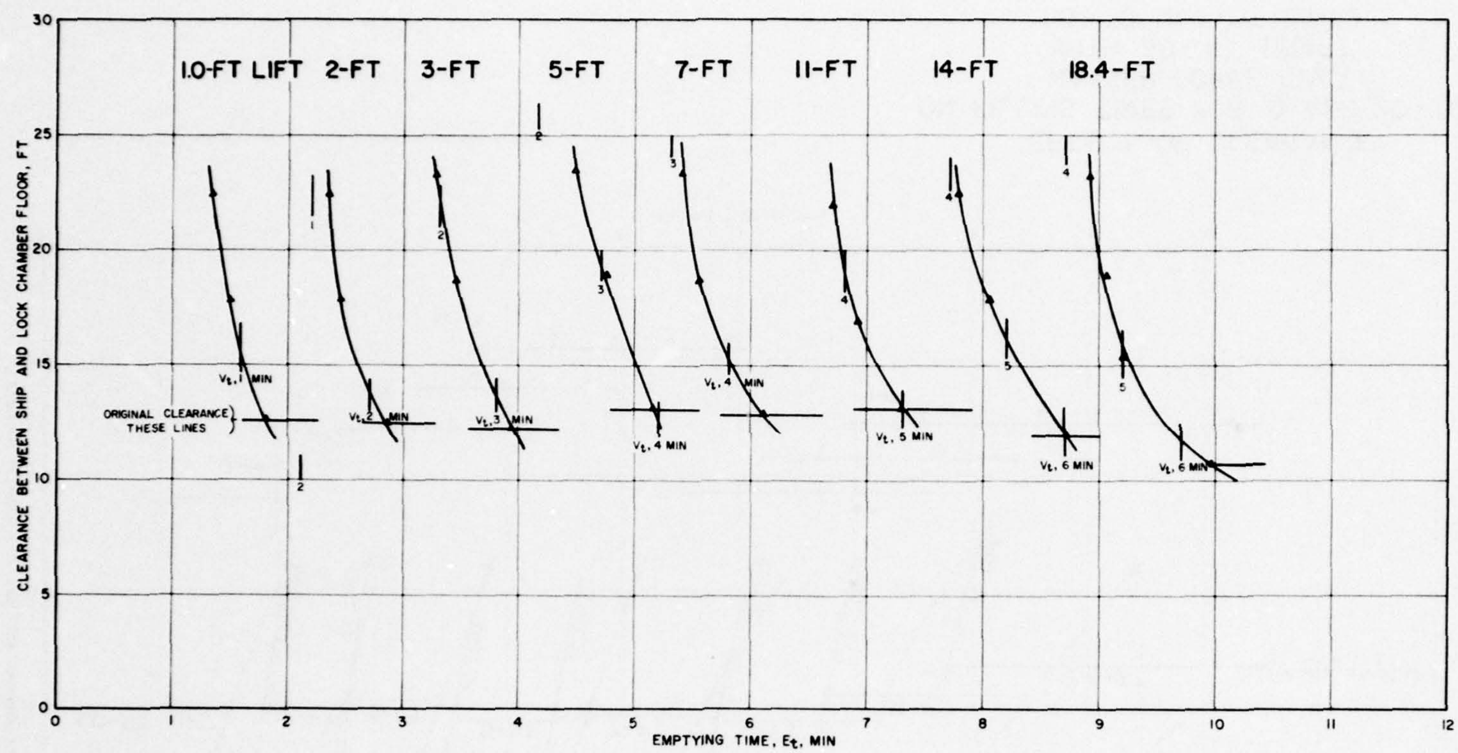
TYPE 15 PORT ARRANGEMENT



NOTE: 37.5-FT SHIP DRAFT WAS DISPLACEMENT OF 142,500 TONS.

EFFECT OF CLEARANCE
ON EMPTYING TIMES FOR 25-TON
HAWSER FORCE LIMIT
WITH 37.5-FT DRAFT
1.0- TO 18.4-FT LIFTS

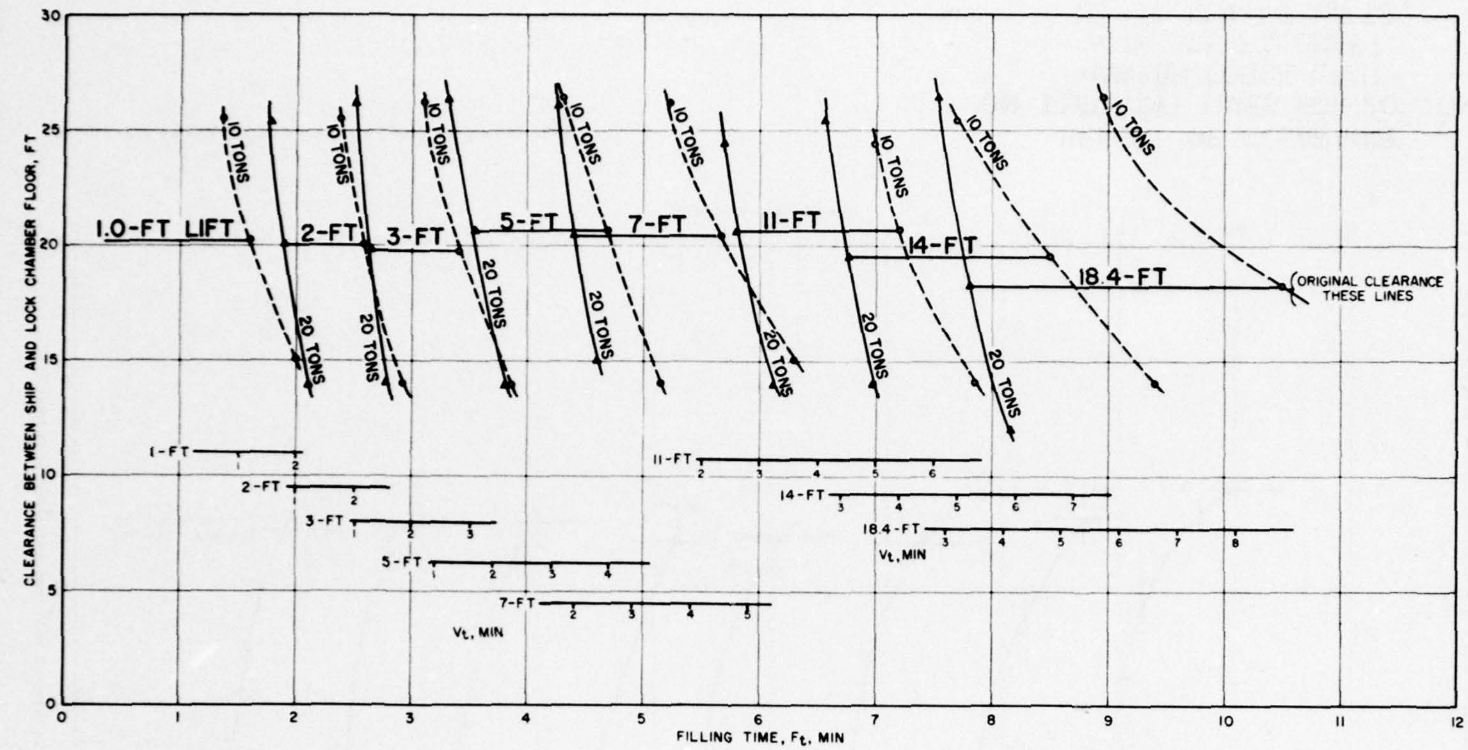
TYPE 15 PORT ARRANGEMENT



NOTE: 37.5-FT SHIP DRAFT WAS DISPLACEMENT OF 142,500 TONS.

EFFECT OF CLEARANCE ON EMPTYING TIMES FOR 20-TON HAWSER FORCE LIMIT WITH 37.5-FT DRAFT 1.0- TO 18.4-FT LIFTS

TYPE 15 PORT ARRANGEMENT

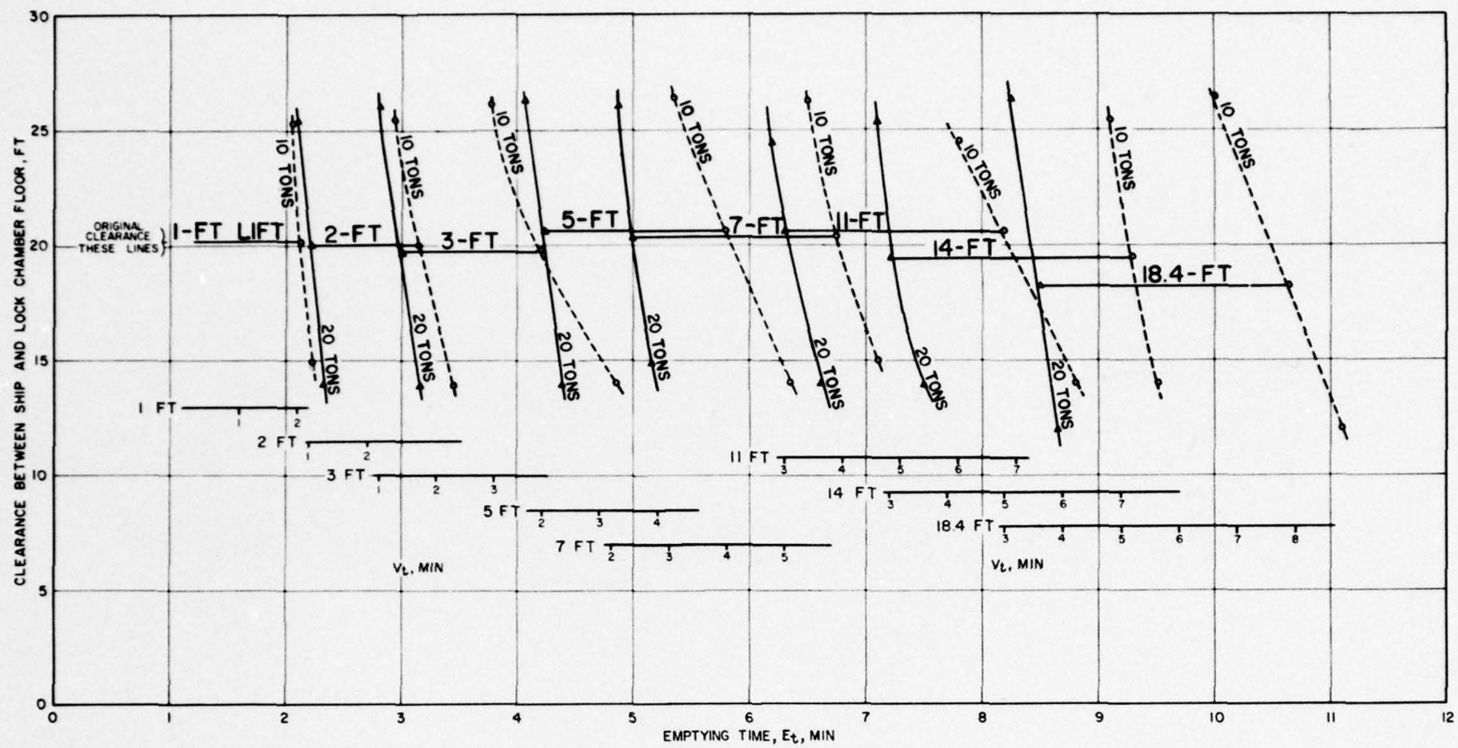


NOTE: 30-FT SHIP DRAFT WAS DISPLACEMENT OF 114,000 TONS.

EFFECT OF CLEARANCE
ON FILLING TIMES FOR 10- AND 20-TON
HAWSER FORCE LIMIT
WITH 30- FT DRAFT
1.0-TO 18.4-FT LIFTS

TYPE 15 PORT ARRANGEMENT

PLATE 42



NOTE: 30-FT SHIP DRAFT WAS DISPLACEMENT OF 114,000 TONS

EFFECT OF CLEARANCE
ON EMPTYING TIMES FOR 10- AND 20-TON
HAWSER FORCE LIMIT
WITH 30-FT DRAFT
1.0- TO 18.4-FT LIFTS

TYPE 15 PORT ARRANGEMENT

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Ables, Jackson H
Filling and emptying system, New Ship Lock, Mississippi River-Gulf Outlet, Louisiana; hydraulic model investigation / by Jackson H. Ables, Jr. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
34, [7] p., 43 leaves of plates : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; H-78-16.
Prepared for U. S. Army Engineer District, New Orleans, New Orleans, Louisiana.
References: p. 34.

1. Hydraulic models. 2. Lock filling and emptying systems. 3. Locks (Waterways). 4. Mississippi River Gulf Outlet. 5. New Ship Lock. I. United States. Army. Corps of Engineers. New Orleans District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; H-78-16.
TA7.W34 no.H-78-16